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RESEARCH REPORT

1961

COFFEE RESEARCH STATION

LYAMUNGU

TANGANYIKA

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RESEARCH REPORT
1961

COFFEE RESEARCH STATION
LYAMUNGU

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COFFEE RESEARCH SERVICES
TANGANYIKA

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INTRODUCTION

The weather conditions during 1961 in terms of meteorological records are considered in some detail elsewhere in the Report this year. In general at the Coffee Research Station, Lyamungu, rainfall has been unusual in that the Long Rains were rather deficient whereas the Short Rains were very excessive; distribution was not on the whole unfavourable to judge by the reaction of the coffee tree itself and the application of only a little irrigation was necessary over the greater part of the year.

Nevertheless, the very heavy rainfall in the last quarter of the year has produced several rust generations, despite a careful attempt to time copper spraying more precisely; it remains to be seen to what extent we can reduce the level of infection that has built up by further precise timing of copper sprays before the onset of the Long Rains in April 1962.

The 1960/61 coffee crop on Lyamungu was a good one. From 142.9 acres of coffee a crop of 99.37 tons of clean coffee (mean yield 13.90 cwt. per acre) and a further 15.93 tons of buni (overall mean yield 16.13 cwt. per acre) was harvested. The proportion of the crop which was classified as three or upwards was 27.30% and 77.07% was class 6 or better; grade PB, AA and A together constituted 37.17% of the crop, inclusion of B grade raised the proportion to 68.58%.

A total of 3,901 lb. of coffee seed from Lyamungu selections was sold during 1960/61 season; of this total, 2,151 lb. went to African Growers through Co-operatives, 1,680 lb. went to Plantations and 70 lb. was sold outside Tanganyika.

The Specialist Staff position has improved slightly during the year. Whilst we have failed to recruit a Chemist, we have obtained a Plant Physiologist with the appointment of Mr. R. A. Bull in June. There is a large amount of important and necessary study to be undertaken in this discipline. Mr. H. W. Mitchell was appointed Agronomist on transfer from the Maruku Coffee Experimental Station and again a most essential post has been filled at last. Mr. D. A. Burdekin who was previously visiting Coffee Pathologist, has been transferred as permanent Plant Pathologist on his return from leave. Mr. J. M. C. Brownbridge has been appointed Coffee Processing Officer, and will advise on factory construction and processing; this appointment emphasises the realisation by the Industry that quality coffee production is an essential to a ready sale on present day markets.

Mr. M. B. B. Mangale is to be congratulated on his promotion to Field Officer and has taken up the duties of Farm Manager on the Usagara Demonstration Farm. Mr. S. B. A. Mamiro is also to be congratulated on his well deserved promotion to Senior Field Assistant and he has taken up the duties of Assistant Farm Manager on the Coffee Research Station, Lyamungu.

Mr. M. E. A. Materu, Assistant to Entomologist, is now completing post graduate studies in the U.S.A. and Mr. S. D. Pyman resigned from his post of Farm Manager, Coffee Research Station, Lyamungu.

On the Experimental Stations, Mr. I. J. Thomson left Mbimba in July and has been succeeded by Mr. K. A. Fairweather; Mr. J. Russell took over the running of Mitalula and following the transfer of Mr. Mitchell to Lyamungu, Mr. J. N. Auckland succeeded him at Maruku.

We are therefore gathering together the nucleus of a research team at Lyamungu which will enable us to pursue our work with the team approach which

is so essential to many of the subjects which there are to be studied. Reference has been made to the appointment of a Manager to the Usagara Demonstration Farm. During 1961 a start was made to put all the operations on a detailed cost accounting system which will permit the analysis in detail of specific coffee farming operations.

On the research side 1961 has been a year of consolidation and reorganisation on the one hand and increased activity of advisory and extension work in the field, on the other. Mr. L. M. Fernie, Horticulturist, was attached to East Malling Research Station for a period of three months during which (a) all the coffee selection work carried out on Lyamungu over the past 25 years was reviewed and the future programme of work re-defined and (b) the preliminary work begun in a small way in 1952/53 on Arabica coffee breeding was reviewed and a programme for the future agreed. Because of the advantages to be gained from Arabica breeding work throughout East Africa it has been possible to broaden the aspect of this work to an inter-territorial venture embracing Kenya and latterly Uganda as well. Very close collaboration to the mutual advantage of all participating members now seems assured.

During 1961 also, a new organisation for considering current research work and advising on new research to be undertaken was set up. This consists of three Area Coffee Research Advisory Committees, namely the Northern Area C.R.A.C. (Arabica research), the Southern Area CRAC (Arabica research) and the Western Area C.R.A.C. (Robusta and Arabica research). To date two of these Committees have met and the third will meet during 1962.

Research carried out on Mount Kilimanjaro during 1958-61 on the coffee holdings of African growers has revealed the substantial responses that may be obtained under conditions of good basic coffee culture, to the application of copper fungicide sprays. In co-operation with the Extension Services of the Department of Agriculture a project was initiated in October under the Three Year Agricultural Development Plan, which sets out to examine quite extensively the economics of copper fungicide and fertilizer applications to the coffee on the farms of African growers. A total of 104 such farms are covered by this project which will continue for a full three years.

Finally, there has been considerable extension and advisory activity by the Senior Specialist Staff from the Coffee Research Station, Lyamungu. A total of 108 visits to plantations have been made and a total of 73 days safari has been carried out in the African coffee areas.

I should like to record my thanks and appreciation to the Staff at all levels, for completing a good, strenuous year's work.

J. B. D. ROBINSON,

Principal Scientific Officer

PUBLICATIONS:

The following papers were published in the *Tanganyika Coffee News* during 1961:

January.	"The Incidence of Parathion Spray Poisoning in Spray Operators," by R. G. Taplay and S. Znatowicz.
February.	"Mulching for Increased Quality Coffee Production," by J. B. D. Robinson.
March.	"Nitrogen Fertilizer Application to Mature Coffee," by J. B. D. Robinson.
	"Coffee Growing in the Mbozi District," by J. I. Thomson.
April.	"Notes on a Brief Visit to the Babati Area," by J. B. D. Robinson.
	"The Planting and Care of Coffee Seedlings," by L. M. Fernie.
May.	"The Possibilities of a New Nursery Technique for Coffee," by L. M. Fernie.
June.	"Farmers Day at Mbozi," by J. I. Thomson.
	"Leaf Rust Epidemics on Kilimanjaro," by R. G. Tapley.
July.	"Spray Programme for Arabica Coffee," by R. G. Tapley.
September.	"Diebacks, Leaf Shedding and Abnormal Growth in Coffee at Mbozi", by J. I. Thomson.
October.	"Is Your Coffee Acreage Fully Planted?", by J. B. D. Robinson.
December.	"Mechanisation of Coffee", by S. D. Pyman.

PAPERS PUBLISHED IN OTHER JOURNALS :

Tapley R. G.,
Crinkle-Leaf of Coffee in Tanganyika. Kenya Coffee, 1961, 26, 156.

Tapley R. G.,
Microbial Control of Lepidopteran Coffee Pests. Kenya Coffee, 1961, 26, 213.

Robinson, J. B. D. and Bull, R. A.
Debility Growth Symptoms in Arabica Coffee. Kenya Coffee, 1961, 26, 251.

Robinson J. B. D., Nitrogen Studies in a Coffee Soil.,

Part II. The influence of mulch on natural and fertilizer levels of nitrate and ammonia in the topsoil. J. Agric. Sci., 1961, 56, 49.

Part III. The Comparative efficiency of ammonium Sulphate and urea fertilizers in the presence and absence of an organic mulch measured in terms of crop yield. J. Agric. Sci., 1961, 56, 61.

Robinson, J. B. D.
Mineral to Nutrition of Coffee. Preliminary results with the leaf analysis technique. E. A. Agri. J., 1961, 27, 1.

Robinson, J. B. D.
A note on Magnesium Unbalance Symptoms in Advocado Pear trees. E. A. Agr. J., 1961, 27, 47.

Robinson, J. B. D.
Mulch your Coffee for Higher Yields and Better Quality Crops. Ukulima wa Kisasa, July, 1961.

Tapley R. G.,
The use of Copper Fungicides in Coffee can Increase Production. Ukulima wa Kisasa, October, 1961.

Extension Pamphlets on the following special subjects have been issued to the Extension Service, Department of Agriculture, during 1961. These are in addition to reprints of relevant papers which have been published in Tanganyika Coffee News :

1. Some simple rules for Multiple stem pruning of Arabica Coffee (English and Swahili)
2. Some simple rules for Single stem pruning of Arabica Coffee (English and Swahili)
3. Antestia Control for 1961/62 (English and Swahili)
4. Copper spraying in Peasant grown coffee. (English and Swahili)
5. Simple multiple stem pruning of Arabica Coffee. (English).

CLIMATE

1961 was unique amongst all years yet recorded at Lyamungu in that an abnormal drought was experienced during the first half of the year. The Long Rains were virtually non-existent, as elsewhere in the Northern Province, and an exceptional rainfall of 26 inches was experienced in November. This brought the yearly total to near-average, but the distribution was completely atypical. The number of days when rain fell was above average, particularly during the last 4 months of the year, but the amounts per fall in the normal Long Rains period were far below average. The absence of rains at the usual time tended to make the first half of the year hotter than normal, while abnormal rains late in the year produced more equable conditions, maximum temperatures being lower and minimum temperatures, higher, than usual. The influence of abnormal rainfall distribution is also evident in the humidity figures. Hours of sunshire were not very different from normal but solar radiation was higher than average for every month except November.

The data are summarised for 1961 in Tables 1 and 2 and have been compared with the 11 year period, 1950—1960.

TABLE 1

	Rainfall Boma (inches)		*Rainy Days Boma*		*Mean Maximum Temperature* (oC)		*Mean Minimum Temperature* (oC)		*Absolute Maximum Temperature* (oC)		*Absolute Minimum Temperature* (oC)		*Air Temperature* (0900) (oC)	
	1961	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*
JAN.	0.24	2.88	3	7	30.2	28.5	13.7	14.4	31.9	31.0	11.9	11.7	20.8	20.3
FEB.	0.92	2.34	7	6	28.8	28.4	14.5	14.2	32.0	31.2	12.8	11.9	21.1	20.2
MARCH	0.99	3.34	8	12	29.5	27.8	15.1	14.8	31.9	30.4	12.0	12.4	21.4	20.2
APRIL	5.24	18.57	22	24	27.1	25.0	15.9	15.8	30.0	28.2	12.9	12.7	20.0	18.7
MAY	5.59	15.67	20	25	25.3	22.5	16.2	15.4	28.7	25.2	14.9	12.4	18.5	17.2
JUNE	0.55	3.93	10	16	23.5	21.4	14.6	14.0	25.0	24.1	11.9	11.1	17.6	15.9
JULY	5.32	1.97	16	13	22.0	20.7	14.1	12.9	24.9	23.3	10.5	10.4	16.6	14.9
AUG.	0.64	1.10	7	8	21.9	21.9	14.1	12.9	25.5	24.8	11.9	9.7	16.1	15.3
SEPT.	4.30	0,98	17	6	22.9	24.0	14.1	12.8	29.0	27.1	12.3	9.7	16.6	16.5
OCT.	4.90	0.75	21	6	25.1	26.0	14.4	13.3	27.5	29.1	11.0	10.2	19.1	18.3
NOV.	26.24	3.28	25	10	23.1	27.0	15.4	14.0	25.5	29.9	11.1	11.4	19.4	19.6
DEC.	9.62	2.10	19	9	24.9	27.7	15.1	14.3	28.5	30.1	13.0	11.9	21.4	20.1
TOTAL	64.55	56.91	175	142										
MEAN	—	—	—	—	26.4	25.1	14.8	13.9	28.4	27.9	12.2	11.3	19.1	18.1

TABLE 2

	Air Temperature (1500) (oC)		*Relative Humidity (0900) (%)*		*Relative Humidity (1500) (%)*		*Evaporation (Piche) (24 hours) (ml.)*		*Evaporation Piché * (6 hrs.) (ml.)*		*Daily Sunshine (hrs.)*		*Daily Solar Radiation (ml. water)*	
	1961	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1960 1950*	*1961*	*Average 1960-1950*	*1961*	*Average 1950-1950*	*1961*	*Average 1960-1950*
JAN.	28.5	26.9	76	78	45	53	5.8	3.7	2.1	1.6	6.7	5.9	14.5	11.4
FEB.	26.2	26.8	62	78	48	53	4.6	4.2	1.7	1.5	5.6	6.1	13.5	10.8
MARCH	26.6	25.9	76	82	54	58	4.9	3.4	1.8	1.2	5.8	4.8	13.2	9.9
APRIL	25.3	23.9	88	91	61	69	2.7	1.8	1.0	0.7	3.7	3.1	8.8	6.7
MAY	23.7	21.5	90	93	64	76	2.4	1.3	0.9	0.5	3.1	2.0	6.6	5.0
JUNE	22.8	20.6	83	90	60	70	2.9	1.9	1.2	0.6	2.3	2.2	6.9	5.0
JULY	21.4	19.9	87	90	62	66	2.4	2.0	1.0	0.7	2.7	2.2	6.1	3.9
AUG.	19.6	21.2	87	89	61	62	3.0	2.4	1.1	0.7	2.0	3.1	7.7	6.9
SEPT.	22.4	23.2	90	88	63	55	2.9	3.1	1.2	1.1	3.0	4.1	9.9	9.2
OCT.	24.3	25.2	84	82	57	51	3.1	3.8	1.3	1.4	4.0	4.7	11.3	10.3
NOV.	22.2	25.4	88	82	76	55	1.6	3.6	0.7	1.3	2.5	4.8	8.7	9.0
DEC.	22.6	26.0	80	79	73	56	2.4	3.7	0.9	1.4	4.1	4.6	11.4	10.4
MEAN	23.8	24.0	83	8.5	6.0	6.0	3.2	2.9	1.2	1.1	3.8	4.0	9.9	8.2

* between 0900 and 1500 hours.

Annual Total Sunshine for 1961— 1346.7 hrs.

Average Annual Total Sunshine for 1950—60 1428.0 hrs.

THE SELECTION OF ARABICA COFFEE AT LYAMUNGU

2. The "KP" Series

By L. M. FERNIE, Horticulturist

INTRODUCTION

The "KP" series of the Lyamungu selections originated in a uniformity trial at the Coffee Research Station on the Southern slopes of Kilimanjaro, at an altitude of approximately 4,200 feet above sea-level. The seed from which the plants were raised was reputedly of the Kent variety and was obtained through the good offices of a local planter having previous association with the coffee plantation industry in Mysore State, South India. The actual purity of the strain and the number of generations removed from Mr. L. P. Kent's original single tree selection are not known.

During the 10 years 1950—59 inclusive, some 13,868 lb. of seed of the "KP" series has been distributed from Lyamungu to growers in Tanganyika. This amount represents 29.6% of all the seed distributed during this period.

As a general rule, Kent selections are heavier yielders than the Bourbon selections, but liquoring quality is usually slightly inferior although still better than fair average quality. The "KP" selections are not exceptions in this respect. They also show the typical Kent reaction to the two common races of leaf rust, (*Hemileia vastatrix*), being resistant to Race II, but they are unfortunately susceptible to the very virulent Race I which causes such damage, particularly at the lower elevations.

It is interesting to note that for many years the original tree of KP.423 maintained its position as the highest yielding tree in the Kents Plot, while its clone occupied a similar position in the clonal trials at Lyamungu. Other favourite selections which have proved their worth include KP.154, KP.162, KP.265 and KP. 532.

There are still some very good selections in the Kents Plot which have never been tested in clonal trials, and therefore unfortunately their seed has never been distributed to growers. These include, amongst others, KP.405 which is now the highest-yielding tree in the Kents Plot with an annual mean yield at the rate of 16.59 cwt/acre clean coffee over 24 years.

Individual tree selection within the first generation of some of the "KP" series raised from clonal seed has revealed some promising material, notable not only for high yield with the best yielding at the mean rate of 27.38 cwt/acre clean coffee per year for the first 6 bearing years, but also for an apparent resistance to the die-back condition and death which has been so prevalent in the area recently.

KENTS PLOT

One of the first plantings on the Coffee Research Station was this original block of Kent's coffee in 1934, when 574 trees were planted; this number was later increased to 787 trees. The single stem pruning system was adopted from the start, although some trees were stumped back for the production of suckers for propagation purposes in the early years. The land is level at one end of the block, while the other end is contained on an easterly slope. The area is shaded with a mixture of *Albizzia maranguensis* and *Rauvolfia inebrians*, which have been regu-

larly thinned and pruned to give a high light shade. The spacing is 9' x 9' square. All plants are copper-tipped, which is a characteristic of the Kent variety to the extent that no true Kent trees are ever green-tipped, but the copper-tip characteristic is commonly found amongst other varieties and strains and must never be used as a positive means of identification of a Kent tree, as is so often erroneously thought by some growers to be the case.

The first yields were recorded in 1938, and after 6 years thirty-nine trees were provisionally selected on their yield performance. The recording of these thirty-nine trees has now continued without interruption for 24 consecutive years, and a wide variation of yields, ranging from a mean 4.37 cwt/acre to 16.59 cwt/acre clean coffee, has been revealed, even within these provisional selections. Only one tree (the untried KP. 405) has exceeded an average of 15 cwt/acre over the 24-year period, but two others have exceeded 14 cwt/acre, viz. KP. 406 (also untried) and the favourite KP. 423. An examination of the best twelve yielders after 24 years recording (Table I) reveals the interesting fact that only four of these twelve were also among the best twelve yielders after 9 years recording, and all four have improved their average yield from the 9th to the 24th year. In fact every one of the twelve best trees after 24 years recording has improved its average yield from that recorded after 9 years. If, however, the yields of the twelve best yielding trees after 9 years are followed through to the 24th year (Table 2), it is found that only six have maintained or improved their mean yield during this period, while the other six have deteriorated. There is therefore a considerable risk of deterioration when high yields are experienced in the early years, but some trees seem able to resist this tendency.

TABLE 1.

Kents Plot — the 12 best-yielding trees in 1961, after 24 years recording.

Tree No.	*Mean annual yields in cwt/acre clean*		
	9 YEARS 1938—46	*24 YEARS* 1938—61	*CHANGE*
KP. 164	8.16	13.44	+
*215	12.88	13.05	+
*265	12.15	12.29	+
352	8.38	11.92	+
362	9.95	12.00	+
405	7.99	16.59	+
406	9.45	14.13	+
*409	10.17	13.75	+
412	8.52	13.92	+
414	7.65	12.72	+
*423	13.41	14.11	+
685	9.13	12.01	+

* These were also among the 12 best trees in 1946 after 9 years recording. (See Table 2).

TABLE 2.

Kents Plot — the 12 best-yielding trees in 1946, after 9 years recording.

Tree No.	Mean annual yields in cwt/acre clean		
	9 YEARS 1938—46	24 YEARS 1938—61	CHANGE
KP. 146	14.14	8.58	—
163	12.17	10.64	—
204	10.54	8.72	—
*215	12.88	13.05	+
227	11.05	8.98	—
231	11.29	9.15	—
262	11.56	9.09	—
*265	12.15	12.29	+
285	10.90	11.53	+
*409	10.17	13.75	+
*423	13.41	14.11	+
683	10.11	11.11	+

* These were also among the 12 best trees in 1961 after 24 years recording. (See Table 1).

CLONAL TRIALS

Clones of thirteen of the thirty-nine potential selections mentioned above were planted out at the Coffee Research Station, with clonal selections from other localities, in a series of 6 x 6 Latin squares during the period 1943-49. The mother trees of eight out of these thirteen clones were included among the twelve best-yielding selections in Kents Plot in 1946, but only two of them are still included among the best twelve in 1961, and these are KP. 265 and KP. 423. The clone of KP. 423 has faithfully reproduced the promise shown by the mother-tree, and some other good yields, examples of which are shown in Table 3, have been recorded.

TABLE 3.

Some examples of the yields, expressed as cwt./acre clean coffee, of selections of the "KP" series and their progeny.

TREE No.	MOTHER-TREE		CLONE		SEEDLING	
	Mean yield	No. of years	Mean yield	No. of years	Mean yield	No. of years
KP. 154	9.90	24	12.45	15	16.05	4
KP. 162	14.49	5	13.29	14	12.46	4
KP. 163	10.64	24	11.52	14	14.88	4
KP. 227	8.98	24	12.76	14	12.65	4
KP. 228	8.19	24	11.29	17	14.81	4
KP. 423	14.11	24	14.62	15	13.50	4
KP. 532	10.90	24	13.21	16	13.93	4
KP. 683	11.11	24	10.49	16	11.29	4

Samples from all the clones in the clonal trials were submitted to a Liquorer for quality reports and classification for 6 or more successive years from 1948 onwards. Although they were neither as good nor as consistent as the 'N' series, the results from the "KP" series were satisfactory, and examples of the classes attained are shown in Table 4.

TABLE 4.

Examples of the quality classes attained by 'A' grade samples of some clones of the "KP" series.

	QUALITY CLASSES							
	KP. 154	KP. 162	KP. 163	KP. 227	KP. 228	KP. 423	KP. 532	KP. 683
1948	3+	2	1	1	2+	1	2+	1
1949	4+	5	4+	4	3—	3—	4	2
1950	2+	2	2—	3	1	2+	—	3+
1951	3	3+	2	2+	1	3+	2	3
1952	4+	3+	1	3+	3—	3	2	2
1953	2	3	2—	2	3	2	2	2+
1954	—	3+	—	—	—	3+	3	—
1955	—	4	—	—	—	4+	—	—

PROGENY TRIALS

The seedling progeny of the most promising clones in the clonal trials, together with the progeny of four first generation selections, were planted out in 1954 in a selection trial known as Experiment XXIV. Included amongst this material were the progenies of eight selections of the "KP" series, while the clone of KP. 265 was used as one of the two standards. The mean yields of the former for the 4-year period 1956-59 are shown in Table 3. It is unfortunate that this trial was heavily attacked first by stem-pitting and then by an unknown dieback, and the losses in recent years have been considerable. As a result, further yields of the progenies will not be available, but the recording of individual tree selections within the progenies continues, and an example of the yields of nine of these within the "KP" series are shown in Table 5.

TABLE 5.

The annual yields, expressed as cwt./acre clean coffee, of some individual tree selections within the progenies of the "KP" series.

	Annual yields in cwt/acre clean coffee						
	1956	1957	1958	1959	1960	1961	*Mean*
KP. 154/530	20.05	26.84	13.15	26.31	35.96	0.00	20.39
KP. 154/996	14.85	29.70	18.24	20.68	31.29	2.12	19.48
KP. 154/1138	27.58	30.02	12.09	45.50	38.40	10.71	27.38
KP. 163/1050	17.71	24.40	11.77	23.44	26.20	0.00	17.25
KP. 227/915	21.64	16.02	11.88	30.76	9.86	0.00	15.03
KP. 228/774	15.38	17.71	10.18	27.15	30.12	17.18	19.62
KP. 423/967	20.26	12.20	12.20	15.91	30.34	2.97	15.65
KP. 532/472	17.61	19.09	12.94	36.06	22.70	7.32	19.29
KP. 683/500	26.31	18.46	11.35	13.79	62.48	0.00	22.07

The annual yields of tree No. KP. 154/1138, giving a mean yield at the rate of 27.38 cwt/acre clean coffee for 6 years, should be especially noted. This tree is pruned on the multiple stem system.

EXTERNAL TRIALS

The "KP" series were not well represented in the earlier external trials, because these selections were made much later than those located on established plantations.

Yields from external trials are also generally lower than those at Lyamungu, but annual mean yields of 16.33 cwt/acre clean coffee over 6 years for KP.228, and 14.16 cwt/acre for KP.423 at Mbosho (altitude 3,700 ft.) have been recorded.

BREEDING

KP.423 was introduced into a pilot inter-selection breeding programme which was commenced at the end of 1952. Early results of a cross with a selection within the Geisha variety have been promising in terms of yield, hybrid vigour, and field resistance to leaf rust (2). Preparations are being made for the detailed screening of this and other hybrid material for the further betterment of planting material.

THE "KP" SERIES ABROAD

In 1952 a small quantity of seed of a number of Lyamungu selections, including four of the "KP" series, was sent to the U.S. Department of Agriculture, for the American P.E.I.—Point IV Programme. It is material from this source that has been disseminated to various coffee-growing countries in Central and South America, as well as to the Coffee Rust Research Centre in Portugal. Seed has also been sent to other countries for trial purposes from time to time. The following reports on the behaviour of some of the selections of the "KP" series abroad have been published :—

Portugal (3) — testing for reaction to the various races of leaf rust (*Hemileia vastatrix*) gave the following results :

KP.228—Group D (susceptible to Races I and VIII only)
KP.263—Group D (" " ")
KP.423—Group D (" " ")
KP.532—Group D (" " ")

U.S.A. (Miami, Florida) (4)

—studying cold tolerance within the genus *Coffea* at Miami during the winter of 1959/60, when, during the entire season, $5\frac{1}{2}$ hrs. were recorded below 35°F and 26 hrs. between 35° and 40°F. The following results were observed :—

KP.532—No injury or insignificant damage to margins of a few leaves.

KP.228)
KP.263)—Considerable injury to leaves only or leaf injury with light damage to terminal growth.

—varietal susceptibility to leaf-miner attack. The following observation was made :—

KP.228—this selection was reported to be the least affected by leaf-miner out of a number on trial. In the same report it is also stated that this selection is a small-leaved type, but this is not a normal characteristic of KP.228.

CONCLUSIONS

Provisional selection based on the early yields of individual trees growing in the Kents Plot at Lyamungu has proved to be generally premature, and extreme variation in yield amongst these selections has occurred in later years. After recording for 24 successive years, it has been shown that there is a tendency for those trees with the highest mean yield to have cropped generally at a lower level in the early years, and conversely those with a high early yield have often, though not invariably, deteriorated. The final answer can only be obtained by means of formal trials, preferably clonal, and it is unfortunate that, due to the late development of their potentialities, only two out of the best twelve mother-trees in the Kents Plot have been so tested. KP.423 has proved itself at Lyamungu both as a mother-tree and as a clone, while other especially good-yielding clones are KP. 154, KP.162 and KP.532.

Although the liquoring quality classification of the "KP" series is generally lower and more erratic than that of the "N" series over the same period, it is shown that it is possible to produce some good quality Kent coffee.

Further selection within the progeny of some of the "KP" series shows that there exists some potentially valuable material which must still be proved formally. Not only is this material high-yielding, but it is displaying an apparent field resistance to die-back and death from hitherto unknown causes.

The use of KP.423 in a pilot inter-selection breeding programme has resulted in some hybrids KP.423 x VC.496, among others, exhibiting hybrid vigour, high yields, and a high degree of field resistance to leaf rust (*Hemileia vastatrix*).

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SOME NEW ARABICA COFFEE HYBRIDS

By L. M. FERNIE, Horticulturist

INTRODUCTION

When the coffee research programme for Lyamungu was first drawn up in 1934, it was decided that the main approach to the improvement of the plant material would be by selection. Initially this was within the Territory's existing *arabica* population, but after the establishment of a collection of coffee species, varieties, and selections from all parts of the world, the search for desirable characteristics was widened.

Although yield was the main basis for selection, other characteristics such as vigour, bean size, liquoring quality, and field resistance to leaf rust (*Hemileia vastatrix*) were all recorded or assessed. As a result it was possible by 1952 to select individual trees possessing the desired characteristics, and to incorporate them in a pilot breeding programme.

Since the start of this work, the Coffee Rust Research Centre in Portugal, under the direction of Dr. Branquinho d'Oliveira, has isolated twelve physiologic races of leaf rust (nine infecting *arabica*) and has grouped hundreds of coffee seedlings of many types into eleven groups (of which eight are *arabica*), according to their reaction to the various rust races. The present extent of our knowledge (1, 3) shows that two of these rust races are locally endemic in the Northern Province of Tanganyika. Providing that the genetics of the rust fungus conforms to the suspected pattern, genes from the parents used in some of the initial series of crosses should be capable of conferring resistance not only to the locally endemic rust races, but also to all the other races at present known to infect *arabica* coffee.

THE PARENT MATERIAL

The inter-selection crosses and selfings with which this paper is concerned, are those carried out in November 1952 and January 1953, and are collectively referred to as the 1952/53 series. The origins and details of the five selections chosen as parents in this pilot programme are summarised in Table 1 :—

TABLE 1

The parents in the pilot breeding programme.

Selection	Variety	Origin	Characteristics
H. 66	Kent	Machame — Kilimanjaro	Vigour — bean size — yield
KP. 423	Kent	Lyamungu — Kilimanjaro	Yield
N. 39	Bourbon	Kilema — Kilimanjaro	Quality — yield
VC. 496	Geisha	Lyamungu ex Ethiopia	Rust resistance
VC. 541	Amphillo	Lyamungu ex Ethiopia	——

It can be seen that three of the selections were of local origin, and the behaviour of both the original mother-tree and the clone was assessed in making

the choice. Of the other two, the Geisha selection was chosen for its observed field resistance to leaf rust at Lyamungu, and the Amphillo was another strain to which no particular characteristics could be assigned and which was included solely on account of its Ethiopian origin.

THE ESTABLISHMENT OF THE 1952/53 SERIES

The operations concerned with the crossing and selfing necessary to produce this series were commenced in November 1952, and were continued at the time of a further flowering in January 1953. The technique used for emasculation was that developed by Krug (2). Branches of emasculated flowers and those of the pollen-bearing flowers were enclosed in muslin sleeves supported on a frame of wire or bamboo.

The fruits were harvested during the period August to November 1953, and the seeds were eventually sown in the nursery on the 7th April 1954, the normal flat-sided seeds and the peaberries being kept separate in each case. The unavoidable delay in sowing the seed was unfortunate and it is probably the main reason for the erratic and sometimes poor germination results. Thus the population sizes, already rather small due to the number of crosses attempted, the limited supply of flowers, and difficulties of technique, were still further reduced.

Details regarding the establishment of this series are shown in Table 2 below :—

TABLE 2

The establishment of the 1952/53 series.

Cross	Flowers Pollinated	Fruits Harvested	Seeds Sown			Seedlings Planted
			Ordinary	Peaberry	Total	
H 66 selfed. - - - -	32	24	31	4	35	19
H.66 x KP. 423 - - -	82	55	64	12	76	48
H.66 x N. 39 - - - -	106	28	17	18	35	17
H.66 x VC. 496 - - -	64	45	71	9	80	61
H 66 x VC. 541 - - -	55	19	11	12	23	14
KP. 423 x H.66 - - -	55	50	79	9	88	65
KP. 423 x N. 39 - - -	80	40	51	14	65	46
KP. 423 x VC. 496 - - -	23	21	37	2	39	32
KP. 423 x VC. 541 - - -	16	9	16	1	17	11
N. 39 selfed - - -	143	118	174	25	199	47
N. 39 x H.66 - - -	88	54	52	27	79	58
N. 39 x K.P. 423 - - -	52	40	58	11	69	48
N. 39 x VC. 496 - - -	45	41	62	9	71	44
N. 39 x VC. 541 - - -	38	36	44	14	58	44

The seedlings were planted out at a spacing of 9 feet x 9 feet square in an unshaded Observation Plot on the 19th April, 1955, the progenies and the plants within the progenies being planted successively within the rows; a record was kept of the type of seed from which each plant was derived. All plants from the

seed beds were planted without any form of nursery selection, and plants which failed to become established, or which subsequently died, were replaced by the clone of the seed-bearing parent.

The plants were pruned on the single stem system, as this affords an easier method of general assessment and reduces the difficulties consequent upon breakages and cycle changes. The first capping of the main stem, at 21" above ground level, was carried out in January 1956. The first flowering occurred at the end of that year and a heavy first crop was harvested in 1957.

RESULTS

The results obtained from yield records for four years from 1957—1960, the assessment of field resistance to leaf-rust (*Hemileia vastatrix*) from June 1957 to November 1960, stem diameter measurements as an expression of hybrid vigour at five years after planting in the field, and quality reports for the 1960 season are summarised below.

YIELDS

The mean yields for four years, and the mean yield range covering the same period, of the F1 generation are shown in Table 3, expressed as cwt. clean coffee per acre. The superiority of the x—VC.496 progenies is immediately apparent; they have given a higher mean yield and a higher mean yield range in each case. The H.66 x VC.496 progeny are particularly outstanding.

TABLE 3.

Four-year mean yields and four-year mean yield ranges of the F1 generation, expressed as cwt. clean coffee per acre.

MALE PARENT	FEMALE PARENT						Overall Mean Yield
	N. 39		H. 66		KP. 423		
	Mean Yield Range	Mean Yield	Mean Yield Range	Mean Yield	Mean Yield Range	Mean Yield	
N. 39	3.69 — 16.29	11.41	6.87 — 16.65	11 42	6 11 — 18.18	12.38	11 73
H. 66	6.46 — 18.79	11.79	6.60 — 15 47	11.89	3 37 — 16 97	12.15	11.94
KP. 423	4.03 — 17.95	11.59	4.97 — 14.59	11.33	——	—	11.46
VC. 496	5.75 — 20.62	14.90	9.87 — 24.84	18.16	8.46 — 20 46	16.02	16.36
VC. 541	6.08 — 16.59	10.84	11.09 — 18.92	14.41	4.50 — 14 92	12.72	12 65
MEAN		12.10		13.44		13.31	—

Further examination of the mean yields of the F1 generation shows that a high proportion of the progenies of x-VC.496 have exceeded a mean annual yield of 15 cwt. clean coffee per acre, which has hitherto been the yield target for selection. The details, which are given in Table 4, emphasize the influence of the parent VC.496 on the progeny yields.

TABLE 4

Percentage of the total number of plants within each progeny with a mean yield exceeding 15, cwt. clean coffee per acre per annum over four years.

MALE PARENT	FEMALE PARENT		
	N. 39	H. 66	KP. 423
N. 39	6.8	6.3	17.9
H. 66	7.7	11.8	7.0
KP. 423	8.9	0.0	—
VC. 496	55.0	72.7	66 6
VC. 541	4.9	30.8	0.0

RUST RESISTANCE

A system of scoring for leaf-rust (*Hemileia vastatrix*) susceptibility in the field, according to the number of leaves per tree naturally infected with sporulating rust lesions, was initiated in July 1957, and continued every other month. The consistently low mean rust score for all progenies with VC.496 parentage is strikingly apparent in Table 6, where the range of these scores within each progeny is also shown. The lower limit of the x-VC.495 progenies represents a high degree of apparent field resistance, while the upper limit of the same progenies often approximates to the lower limit of the others.

Copper sprays have of course been withheld from these trees since these observations were started.

TABLE 5.

Mean score and range of the score of the F1 generation for leaf-rust infection in the field: July 1957—November 1960.

MALE PARENT	FEMALE PARENT					
	N. 39		H. 66		KP. 423	
	Mean Score Range	Mean Score	Mean Score Range	Mean Score	Mean Score Range	Mean Score
N. 39	62 — 95	80.02	44 — 74	55.00	41 — 92	69.07
H. 66	35 — 82	63.30	32 — 52	39.82	33 — 64	48.96
KP. 423	38 — 75	57.32	32 — 57	46.82	——	—
VC. 496	8 — 39	20.95	6 — 44	16.07	13 — 45	21.70
VC. 541	37 — 90	68.36	42 — 60	51.23	38 — 68	50.30

As a result of the screening work by d'Oliveira and Rodrigues (4), seedling progeny of the selections used as parents above have been generally assigned by these workers to groups as shown in Table 6, according to their reactions to the various rust races. It must be emphasized, however, that these reactions have not yet been confirmed for the clones of these selections; it is proposed that they will be investigated shortly.

TABLE 6.

Leaf rust reaction groups, according to d'Oliveira and Rodrigues (4) and d'Oliveira (3).

Selection or Variety	Seedling No	Reaction Group	Rust races to which susceptible	Rust races to which resistant
N. 39	80	E	All infecting arabica	Nil
	213	D	I, VIII, XII	II, III, V, VII, IX, X
H. 66	93	D	I, VIII, XII	II, III, V, VII, IX, X
KP. 423	108	D	I, VIII, XII	II, III, V, VII, IX, X
	212	D	I, VIII, XII	II, III, V, VII, IX, X
* Geisha	87	C	III, X	I, II, V, VII, VIII, XII
** Amphillo	79/3	D	I, VIII, XII	II, III, V, VII, IX, X
	79/1, 2, 4	E	All infecting arabica	Nil

* VC.496 is one of the trees from which the Geisha material (P.I.205928) was obtained..

** VC.541 is one of the trees from which the Amphillo material (P.I.205927) was obtained.

Hybrid Vigour

It was obvious at an early stage that the progenies of x-VC.496 were displaying exceptional vigour. After three years in the field, the branches of most of these plants intermingled at a spacing of 9 feet x 9 feet apart. In April 1960, (five years after planting in the field) diameter measurements of the main stem were taken at 6" above ground level. These measurements, which are in fact the mean of two diameters at right angles, showed greatly increased mean stem diameters in respect of the x-VC.496 progenies, and the results are summarised in Table 7. It seems reasonable to assume that hybrid vigour is responsible.

There is no correlation between yield and stem diameter of trees within the progenies, and the stem diameter measurement is here regarded solely as an expression of hybrid vigour.

TABLE 7.

Mean stem diameter in mms. at 6" above ground level, five years after planting in the field.

MALE PARENT	FEMALE PARENT		
	N. 39	H. 66	KP. 423
N. 39	76.1	76.2	74 4
H. 66	74 8	75.1	73.5
KP. 423	74.7	74.3	—
VC. 496	84.3	83.5	84.8
VC. 541	69.5	77.3	75.1

Quality classification and grading

The selection VC.496 itself produces a rather small bean, but when it is crossed with the other selections the bean size is generally up to the standard of the

others. An example of the percentage in the first three grades AA, A, and PB for each cross is shown in Table 8 where the results for 1960 are presented.

Similarly the quality classification, based on the appearance in the raw and the roast and on the cup quality, is generally acceptable and better than fair average quality (Class 6). The results of the classification of the 'A'-grade samples for the 1960 season are also given in Table 8.

TABLE 8

Percentage in the first three grades—AA, A, and PB, and quality classes achieved by 'A'-grade samples in 1960.

MALE PARENT	FEMALE PARENT					
	N. 39		H. 66		KP. 42	
	Percentage in first 3 grades	Quality Class	Percentage in first 3 grades	Quality Class	Percentage in first 3 grades	Quality Class
N. 39	74.7	4	74.7	4	65.3	4
H. 66	74.2	4	72.6	4	83 4	4
KP. 423	51.4	4	78 7	4	—	—
VC. 496	67.5	4	83.7	4—	79 0	4
VC. 541	40.8	4—	86.3	4—	58.0	5+

DISCUSSION AND CONCLUSIONS

The above results provide convincing evidence that some outstanding new hybrids of immediate commercial value to the industry have been produced by crossing the Geisha selection VC.496 with the three Lyamungu selections N.39, H.66, and KP.423.

The apparent hybrid vigour, which is likely to be responsible for the high yields, is considered to be a great advance in the quest for higher-yielding material. It will be necessary to resort to vegetative propagation, however, in order to take advantage of this characteristic, and it is perhaps fortunate that some time was devoted to the study of the rooting of coffee cuttings in the past at Lyamungu.

The field resistance to leaf rust (*Hemileia vastatrix*) displayed by these same hybrids is also most encouraging, and it is now intended that each plant of the F1 generation will be screened initially for the two common rust races I and II, and ultimately for the remainder. Final selections will then be based on rust resistance and yield, and these will be further screened for quality. It should be noted that d'Oliveira's definition of resistance (4) has been followed here, and includes immunity, flecking, tumefactions, chlorotic spots, and necrotic points. It is still not known whether these reactions are identical with the local condition known as 'weak-spotting', nor is it known to what extent these reactions may be responsible for premature leaf fall.

Liquoring tests carried out to date indicate that the beans from the hybrids are commercially acceptable, although there may be some room for improvement. The final selections will be exhaustively tested for this important aspect, and if necessary attempts will be made to improve quality by back-crossing the otherwise acceptable selected hybrids to N.39. Similarly, the bean size of the final selections will be checked over a number of seasons to ensure that the small bean which is generally a characteristic of VC.496 is not perpetuated in the hybrid progeny.

The new hybrids would appear to be combining the following characteristics:

(1) Hybrid vigour;
(2) High yield;
(3) Resistance to leaf rust;
(4) Acceptable bean size;
(5) Acceptable liquoring quality.

The final individual tree selections will be made from the F1 after they have been screened for the various rust races. Clones of these selections will be built-up and multiplied as rapidly as possible by means of cuttings with the ultimate object of introducing and distributing clonal material of these hybrids to the growers.

SUMMARY

Details are given of the establishment of a series of inter-selection crosses and selfings which comprise a pilot breeding programme.

Results are given in terms of yield, field resistance to leaf rust, hybrid vigour, quality classification, and grading.

Evidence is presented to demonstrate the outstanding results achieved by the F1 progenies of VC.496, a Geisha selection which was raised at Lyamungu from seed originally obtained from Ethiopia.

After the final individual tree selections have been made, it is intended to establish clones of these hybrids with the ultimate intention of encouraging vegetative propagation of them commercially.

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CROP YIELD AND THE NUMBER OF COFFEE TREES IN THE PLANTING HOLE

By J. B. D. ROBINSON, Principal Scientific Officer

In Brazil, the largest single coffee producing country in the world today, it is standard practice to cultivate four *Arabica* coffee trees in each individual planting hole. Elsewhere in the world, it is usual to plant only one tree in each planting hole and this practice is universal in Tanganyika.

A field experiment was laid down on the Coffee Research Station, Lyamungu, to compare the yields of *Arabica* coffee when planted with one, two and four trees per planting hole. It was considered at the time that where more than a single tree was planted in each planting hole at the conventional spacing of 9 ft. square, there would almost certainly be some mutual suppression of growth and development; this in turn would influence possibly, the pruning system best suited to such plantings and so this trial also contained a comparison between the conventional single stem and multiple stem systems as well as a new "umbrella" system of single stem pruning, at each level of the planting hole treatments.

Unfortunately, it was observed after the fourth crop had been harvested in the 1960/61 season, that there were so many trees missing as a result of unknown disease condition (currently under investigation) that the trial had to be abandoned. However, the results of the four years yield were considered to be of sufficient interest to warrant a report at this stage; the results can only be considered to be preliminary, providing some indication of yield trends. It is necessary also to make it clear that the unknown disease which killed so many trees is not confined to this trial alone and is not a condition resulting from the particular treatments under investigation.

DETAILS OF THE TRIAL

The experiment was planted out in the field in April 1955, on a Kilimanjaro loam soil. This is a red/brown lateritic loam developed over recent volcanic formations, with a clay content of between 60—70%. The trial area was almost flat.

The design of the trial was a 3 x 3 factorial, unconfounded, with 6 absolute replications. The spacing was 9 ft. square from the centre of the planting holes and there were 16 trees per plot. Each plot was split into four sub-plots of 4 trees each, made up of two Bourbon (N. 100, I 60) and two Kent (KP. 532, KP. 163) selections. The coffee was unshaded but was irrigated routinely as and when required during the dry season over the entire experimental period. Routine weeding, pest control and copper spraying, etc., was carried out.

Details of the treatments were :

S^0. One coffee tree per hole at 9 ft. x 9 ft. square.

S^1 Two coffee trees per hole; 2 ft. between plants in a hole and 9 ft. x 9 ft. square between holes.

S^2. Four coffee trees per hope; 3 ft. square between plants in a hole i.e. they were at the corners of a 2 ft. square, with 9 ft. x 9 ft. square between the holes.

P^0. Conventional single stem, capped at 21", 45" and 72".

P^1. Conventional mutiple stem, capped at 21" and 2 heads brought up.

P^2. Umbrella system, capped at 60" and primaries removed to leave 3—4 pairs counting downwards from the top. In all the treatments where there were 2—4 trees in a planting hole the trees were pruned as a single tree i.e. the inside primaries were removed completely except at the very top of the stems.

RESULTS :

The yield results for the first four bearing seasons (1957/58—1960/61) are summarised in Table 1.

TABLE 1.

Mean yields for number of trees per hole and pruning treatments.
(Cwt. clean coffee per acre per annum).

Pruning System	*No. of Trees per Planting Hole*			
	One (S_0)	Two (S_1)	Four (S_2)	Mean
Single Stem (P_0)	7.78 (24)	9.67	12.47	9.98 (72)
Multiple Stem (P_1)	6.95	10.22	11.72	9.62
Umbrella (P_2)	6.38	7.00	10.58	7.99
Mean	7.04 (72)	8.96	11.59	9.19

NOTES : 1. The figures in brackets are the number of plot yields in the means.
2. Least significant differences :
Marginal means = 0.80x; 1.07xx; 1.40xxx.
Body of Table = 1.37x; 1.84xx; 2.41xxx.
3. x = P = 0.05; xx = P = 0.01; xxx = P = 0.001.
4. Coefficient of Variation (4 Seasons) = 12.9%.

Ignoring pruning the marginal means show that for the first four seasons, one tree per planting hole yielded less than two which in turn yielded less than four trees per planting hole. Ignoring the number of trees per planting hole the marginal means show that no significant yield difference was found between conventional single and multiple stem pruning but the Umbrella system of pruning the coffee trees produced lower yields than in either of the conventional methods.

Turning to the interactions between one, two and four trees per planting hole and the pruning system, yields on the single and multiple stem systems of pruning increase with the number of trees in the planting hole; with the Umbrella system the increase with one versus two trees per hole is very small and non-significant. With four trees per hole the increase in yield over one or two trees is substantial.

These results are extremely interesting and suggest many possibilities for experimentation in the future. For example, in the second and subsequent cycles of the conventional multiple stem pruning system it is standard practice to carry three and occasionally four stems on each tree i.e. on one root system. The effect of establishing 3 or 4 trees per planting hole and allowing one stem only to develop on each tree i.e. no capping, pruning each head in the manner of conventional multiple stem, might be a considerable advantage. Each stem would have its own root system instead of sharing one root system. This might mean more root per unit top growth and therefore less crop strain with higher yields as a consequence. Mutual suppression of vertical growth might also result in a longer period between conversions.

CONCLUSIONS

1. It has been shown that over the first four years of cropping, coffee yields increase significantly as the number of trees per planting hole is increased from one to two and four.
2. It is unfortunate that this trial has had to be discontinued because of a disease which has killed out a high proportion of the recorded trees in some plots. However the results are such that the work will be repeated and even elaborated in a further trial to be established at the earliest opportunity.

THE EFFECT OF TIME OF PRUNING TREES ON YIELDS OF ARABICA COFFEE

By J. B. D. ROBINSON, Principal Scientific Officer.

There is a widespread lack of appreciation in the Tanganyika *Arabica* coffee industry, of the value of early pruning following final harvesting. Members of the Coffee Research Station staff are always emphasising this point during advisory tours but it still does not seem to be very generally appreciated.

In 1948 a trial (Experiment XX) was started at the Coffee Research Station, Lyamungu, in mature, shaded single stem coffee to determine the effect on yield of delayed pruning following final harvest. Whilst this trial was concluded some years ago no excuse is offered for summarising the results briefly in this Report since the findings could be applied more generally in the industry with considerable benefit.

DETAILS OF THE TRIAL :

The layout was a randomised block with 6 replicates of 6 treatments per block. The coffee was planted in 1936 and was shaded with *Albizza maranguensis* and *Rauvolia inebrians*; the spacing was 9 feet x 9 feet on the triangle and the trees were of mixed Kent and Bourbon seedling material. Each plot contained 25 recorded trees and was surrounded by a guard row.

The treatments were :

P_0 = Main pruning during the month when harvesting was completed i.e. immediately after harvesting.
P_1 = Pruned one month later than P_0
P_2 = ,, two months later than P_0
P_3 = ,, three ,, ,, ,, P_0
P_4 = ,, four ,, ,, ,, P_0
P_5 = ,, five ,, ,, ,, P_0

The coffee was not irrigated during the trial period but routine cultivation operations, fungicide and insecticide applications were carried out as and when required.

The pruning treatments were commenced in December 1948 and the dates are summarized for the trial period in Table 1.

TABLE 1.
Pruning dates for Experiment XX.

Pruning Treatment.	*Pruning Season*					
	1948/49	1949/50	1950/51	1951/52	1952/53	1953/54
P_0	22/12	21/12	22/11	3/12	2/12	23/12
P_1	24/1	24/1	22/12	3/1	2/1	22/1
P_2	23/2	23/2	22/1	5/2	2/2	23/2
P_3	23/3	22/3	23/2	3/3	2/3	23/3
P_4	25/4	25/4	22/3	3/4	2/4	23/4
P_5	23/5	23/5	23/4	3/5	2/5	23/5

In five out of six seasons pruning commenced in December and was finished on the final treatment, in the following May.

RESULTS :

The yield results for the 6 seasons that this trial was recorded, are summarised in Table II.

TABLE 2.

Time of Pruning Effect on Arabica Coffee Yields.
(Cwt. clean coffee per acre per annum)

Season	*Pruning Treatment*						*Mean*
	P_0	P_1	P_2	P_3	P_4	P_5	
1949/50	14.84(6)	13.32	10.94	9.46	10.16	10.95	11.61
1950/51	10.10	8.20	9.95	9.54	6.24	6.48	8.42
1951/52	20.22	17.94	13.45	15.20	14.57	11.01	15.40
1952/53	7.89	7.07	7.88	6.45	6.62	4.53	6.74
1953/54	19.04	18.22	13.86	17.50	19.47	16.19	17.38
1954/55	5.70	4.77	6.13	4.68	3.09	4.40	4.79
Mean.	12.97(36)	11.58	10.37	10.47	10.02	8.92	10.72
Cumulative Total	77.79	69.52	62.21	62.83	60.15	53.56	

NOTES : 1. Least significant Difference, Time of Pruning Means = 1.60x; 2.17xx; 2.90xxx.
Least Significent Difference, Body of Table = 3.05x; 4.04xx; 5.20xxx.
2. Coefficient of Variation = 24.9%
3. Figures in brackets are the number of plot yields in the mean.

The results in Table II clearly show that if single stem pruning is delayed until 2 months or more after the final crop harvest, a very significant loss of crop results. Pruning immediately after harvest results in the highest yield.

Cumulative crop totals on a per acre basis show the magnitude of loss over a period of 6 crop seasons e.g. about 15 cwts. of clean coffee, if the pruning is delayed for as little as two months following harvest under the conditions of this experiment.

CONCLUSIONS :

It is concluded that shaded single stem coffee should be pruned as soon as possible after the final crop harvest if crop loss in the following season is to be avoided.

It is considered that early pruning is a very desirable practice for multiple as well as single stem pruned coffee, shaded or not, except in one or two exceptional circumstances e.g. after severe overbearing with consequent dieback when it is advisable to wait for recovery growth before pruning.

FOOTNOTE: x denotes significance at $p = 0.05$; xx at $p = 0.01$; xxx at $p = 0.001$.

THE INFLUENCE OF INTERPLANTED BANANAS ON ARABICA COFFEE YIELDS

By J. B. D. ROBINSON, Principal Scientific Officer.

One of the commonest practices amongst African Coffee Growers in Tanganyika is to cultivate *Arabica* coffee and bananas together. In some parts of the country e.g. Mount. Kilimanjaro and Mount. Meru areas, bananas are the primary or main crop and are grown for purposes of subsistance, beer making and as an important cash crop. In these areas coffee has been interplanted amongst the banana clumps as an additional cash crop to increase the income per unit of land. Under these conditions it is usual to find that sufficient fertile land is not available and farms are not large enough to support economically pure stands of both coffee and bananas.

There are other *Arabica* coffee areas in Tanganyika e.g. the Matengos, in Southern Province, where bananas are not the main staple food crop, where land is not lacking for the cultivation of these two crops separately and where *Arabica* coffee is the primary cash crop. Yet even under these conditions the system of coffee interplanted with bananas has been adopted as a standard technique. In some areas of Tanganyika this system of mixed cultivation is practised where shade is unnecessary and in some cases even undesirable for optimum and economic coffee production.

It is generally considered that bananas are not a good permanent shade for coffee although under certain conditions they may be satisfactory as a temporary shade for 4-6 years. The shade cover they provide is uneven, pseudostems tend to fall down and damage the coffee tree; the banana stool or clump spreads irregularly and requires regular attention to keep it growing in the best position; it has a big demand for plant nutrients and soil moisture which is a serious disadvantage in areas of seasonal drought. For these reasons the banana is not generally used in large commercial coffee plantings where shade is a basic cultural practice. It is not used as shade in Kenya *Arabica* coffee areas nor in Ruanda-Urundi where substantial progress in coffee has been made during the post war years (van De Steene, Private Communication).

A number of field trials have been carried out on the Coffee Research Station, Lyamungu with the object of determining the effect of interplanted bananas at varying densities, on *Arabica* coffee yields. The results from these trials are summarized here together with information obtained in a preliminary survey of this subject over small coffee farms on a part of Mount Kilimanjaro.

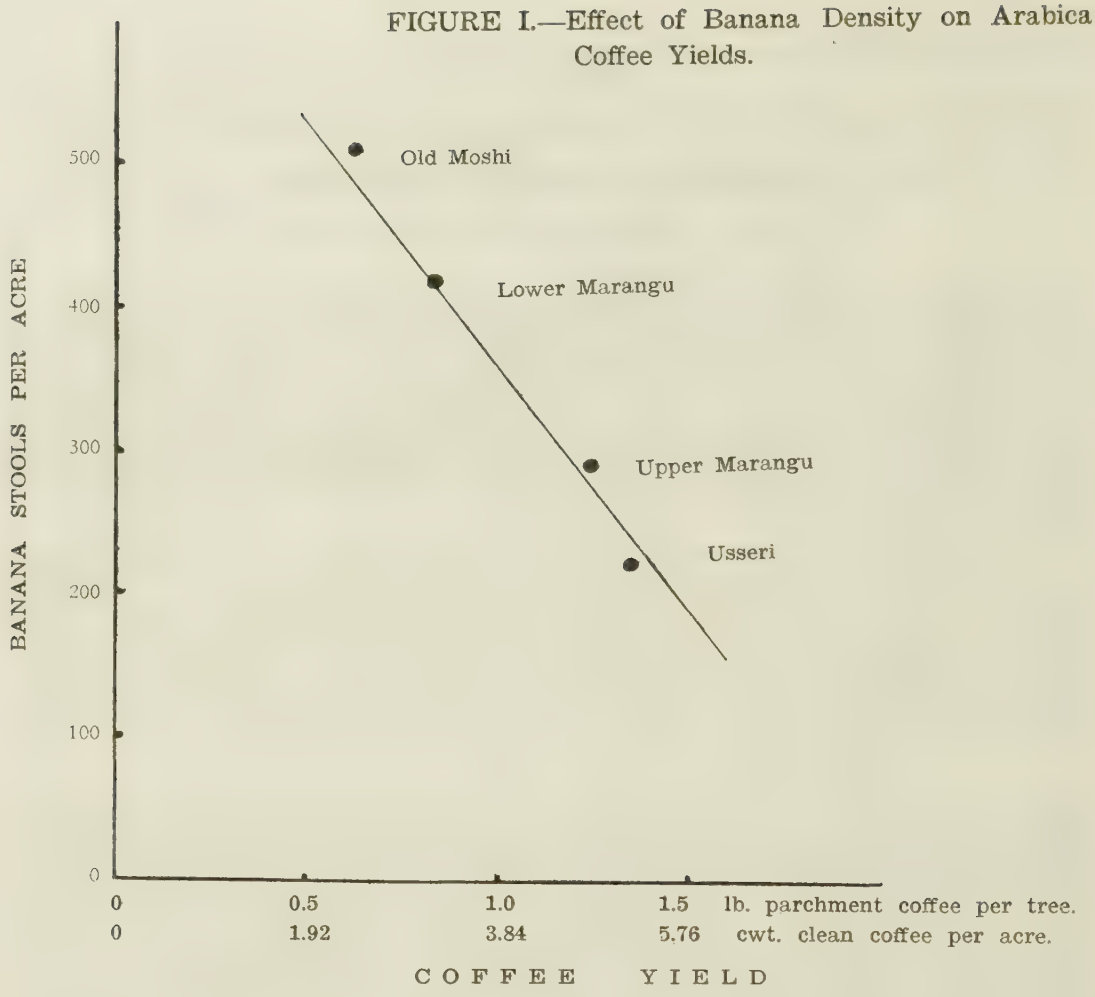
PRELIMINARY SURVEY RESULTS ON MOUNT KILIMANJARO

During 1959, Mr. A. Sykes who was then Agricultural Officer, Moshi, directed a preliminary survey of interplanted banana/coffee farms in the Machame, Usseri, Upper and Lower Marangu and Old Moshi Co-operative Society Districts (1)

The conclusions reached were: —

(i) Increasing populations of bananas reduce yields of parchment coffee per tree.

FIGURE I.—Effect of Banana Density on Arabica Coffee Yields.



(ii) Because of the small acreage of the farms it was concluded that it would be unwise to change the practice of interplanting bananas with coffee as bananas play such an important part in the economy of the holding as well as providing a major food supply for the producer.

(iii) It was also concluded that where farms were large enough for pure stands of bananas to be be grown in sufficient quantity, then a greater return from coffee would also be obtained by planting pure stands of this crop.

(iv) The importance of bananas for cattle feed was noted with particular reference to cattle manure production for application to the bananas and if sufficient is available, to the coffee.

Small though this preliminary survey was the correlation obtained between banana populations and the yield of coffee per tree, computed on a per acre basis, is very close indeed. In Figure I the results for the four Society Districts on the Eastern slopes of Mount Kilimanjaro are summarized. It must be realized however that each of the four points represents a particular Society District as well as a particular mean banana density and the data can be criticised on that point. Unfortunately it is not possible from the data in this Report to examine the yield of coffee under a number of different banana densities in each of the four Districts. Interpolation of the data to a pure stand of coffee (with no interplanted bananas) gives an approximate yield of 2.05 lbs. of parchment per tree or assuming a regular spacing of 9 feet square, 7.86 cwts. of clean coffee per acre; this appears to be a reasonable result.

Experiment XXX and XXXA

This trial, which is in three parts, is primarily concerned with the effect of and interactions between, regular Copper and insecticide sprays. It is planted in three separate blocks to provide for three conditions namely: unshaded coffee (Treatment A), coffee interplanted with bananas (Treatment B) and coffee interplanted with bananas under a high, light indigenous residual forest shade, (Treatment C). The conditions in Treatments B and C are comparable with systems of coffee planting generally used by the African Grower on Mount Kilimanjaro.

The yield results for the first two bearing years from the control, unsprayed plots in each of the three treatments are interesting in that they reflect the extent to which interplanting of bananas has effected cropping levels. In each case the coffee was planted at a spacing of 9 feet x 9 feet square in April 1957; the selection was N 205. (Bourbon). In both Treatments B and C, the bananas were spaced 9 feet x 18 feet apart to give 268 clumps or stools per acre. They were planted in the coffee row to permit mechanical cultivation and spraying in one direction. In Treatment C the tree shade is irregular. The pruning system differs between the blocks; in Treatment A the coffee is uncapped single stem often referred to as free growth; in Treatments B and C the coffee is pruned on the conventional single stem system.

One further point should be made quite clear. The banana interplanted blocks comprise regularly spaced coffee interplanted regularly with bananas. This differs from much of the coffee on Mount Kilimanjaro where the coffee trees have often been interplanted irregularly with bananas, or vice versa. The coffee in Treatment A and B has been irrigated during the dry seasons since planting, as and when necessary.

The yield results are summarized in Table 1.

TABLE 1.

Coffee yields of N 205 with and without interplanted bananas and high light indigenous shade trees, (Cwt. clean coffee per acre per annum).

Year	Treatments		
	Unshaded A.	*Interplanted Bananas* B.	*Interplanted Bananas plus Indigenous trees* C.
1959	2.85 (15).	0.48 (15).	0.12 (18).
1960	13.84 (15).	3.48 (15).	1.93 (18)
Mean of 2 years. ..	8.39 (30).	2.02 (30).	1.05 (36).

NOTES. The figures in brackets are the number of individual tree replicates in each mean.

The reasons for the very large yield differences are not simple to explain. The difference between the methods of pruning referred to above and the difference in the degree of shading of the coffee, will obviously have been partly responsible for the lower yields of treatments B and C compared with A. There is also the possibility of positional differences between A, B C since these are three separate blocks of coffee. Nevertheless, it is considered that some of the yield loss can be attributed to the effect of the bananas interplanted among the coffee trees.

EXPERIMENT XIX

This trial was planted in April 1949 to compare the yield of *Arabica* coffee on the multiple stem pruning system under a high, light shade, with and without interplanted bananas and with and without cattle manure applied to both the coffee and the bananas.

DETAILS OF THE TRIAL

The layout is a randomised block with 8 replicates of 9 treatments per block (3 x 3 factorial arrangement). The coffee is spaced 9 feet x 9 feet square and was planted under a mature mixed tree shade of *Albizzia maranguensis* and *Rauvolfia inebrians*. These shade trees were left growing after selective thinning of the indigenous forest and whilst the shade is uniform over the area as a whole, it is not precisely uniform over individual plots although every trial plot is shaded to some extent by them. The plot size is 36 coffee trees with single tree guard rows around each block.

The treatments are: —

B_0 = No interplanted bananas.

B_1 = Interplanted bananas at 90 stools per acre (6 stools per plot).

B_2 = ... 135 .. .. .. 9 .. .. ..)

M_0 = No cattle manure applied to coffee or bananas

M_1 = 1 debe of cattle manure per annum applied to each coffee tree and banana stool.

M_2 = 2 debes of cattle manure per annum applied to each coffee tree and banana stool.

The bananas are kept to one bearer, one follower and one peeper.

This coffee trial has never been irrigated at any time but it has received routine fungicide and insecticide sprays as and when required.

RESULTS

The yield results for 9 seasons, 1952/53—1960/61, are summarized in Table 2.

TABLE 2.

The Effect of interplanted bananas and cattle manure on yields of multiple stem *Arabica* Coffee (Cwt. clean coffee per acre per annum).

Cattle Manure	*Interplanted Bananas* B0	B1	B2	*Mean*
M_0	8.91 (72)	6.96	7.09	7.65 (216)
M_1	9.16	8.05	6.77	7.99
M_2	8.96	7.92	7.31	8.06
Mean	9.01 (216)	7.64	7.06	7.90

NOTES 1. Least Significant Difference of Marginal Means=0.49x; 0.65xx; 0.86xxx.
Least Significant Difference of Body of Table =0.86x; 1.15xx; 1.51xxx.
2. Coefficient of variation=56.9%
3. Statistical Significance
x at P=0.05; xx at P=0.01; xxx at P=0.001.

The effect on the yield of young coffee, under a light tree shade, of interplanted bananas is very marked at population of 90 stools per acre; increasing this number from 90 to 135 stools per acre leads to a further decrease in mean yield. The cumulative yield totals for the 9 year period at the three levels of banana interplanting and including all cattle manure treatments, emphasise this decrease. These values in cwts. per acre are: B^0=243.35; B^1=206.35; B^2=190.51, a decrease of 37.00 cwts. clean coffee per acre with 90 stools per acre of interplanted bananas and of 52.84 cwts. clean coffee per acre with 135 stools per acre of interplanted bananas. The cumulative loss resulting from an increase of interplanted bananas from 90 to 135 stools per acre, is 15 cwts. clean coffee per acre. Thus the loss in yield attributable to interplanted bananas is approximately linear in this trial up to a population of 135 stools per acre. This apparent linear decrease of coffee yield with increasing banana interplanting is in substantial agreement with the results obtained by the Sykes Survey (1).

Taken over the three levels of banana interplanting, the cattle manure has not increased coffee yields significantly at either of the rates of application on this Kilimanjaro clay loam soil,, under a high light tree shade. This result with particular reference to the B^0 level of banana interplanting, is in agreement with work in Kenya where cattle manure applied to unshaded coffee growing on the fertile Kikuyu red loam soil, has failed to produce significant increases in yield. However, these results are perhaps surprising if it is true that one of the reasons for lower coffee yields when bananas are interplanted is because they are greedy feeders. In this trial though, the bananas were also treated with cattle manure at the same rate as the coffee and the yield reduction brought about by them must probably be attributed to other factors e.g. shade density and/or competition for the limited supply of available soil moisture during the dry seasons.

Experiment XXVIII

This trial was laid down in 1956 to examine the effect of three systems of rejuvenation and pruning of the tree on old estate single stem coffee and the possible effects of interplanting bananas in mature established coffee. At the

time this experiment was planned it was considered that interplanted bananas might interact differentially with the coffee pruning systems.

DETAILS OF THE TRIAL

The layout is a randomised block with 8 replicates of the two main banana interplant treatments, each split into four sub-plots for pruning. The coffee is part of an German planting made in the first part of the 1930's (circa 1932), and is approximately 8 feet x 8 feet square. The coffee was planted under tall, light indigenous forest tree shade following selective clearing. The shade trees are mixed *Albizzia maranguensis* and *Rouvolfia inebrians*. The main plot size is 100 coffee trees with 25 trees in each of the four sub-plots.

The treatments are: —

MAIN PLOTS

B^0=No interplanted bananas.

B^1=Bananas interplanted at a rate of 25 stools per 100 coffee trees i.e. approximately 16 feet x 16 feet, giving 170 stools per acre.

The bananas are kept to one bearer, one follower and two peepers; they were interplanted in the coffee early in June 1956.

SUB-PLOTS

P^0=Leave old single stem tree as it is.

P^1=Convert to multiple stem in normal manner i.e. by cutting off all primaries of 2/3rds of the circumference on the Eastern side of the tree.

P^2=Umbrella system (1).

(a) Cut all primaries off Eastern side of the tree as for P^1 treatment.
(b) Cut back main stem to 4' 6".
(c) Allow one sucker to grow from any point on the main stem.
(d) When new head is cropping cut back old stem to just above base of sucker and remove all remaining primaries from old stem.
(e) Allow new stem to develop umbrella shape.

P^3=Umbrella system (2).

Convert by removing all primaries from old stem except top 6 pairs.

The pruning treatments were carried out in March 1956.

Routine application of fungicide and insecticides have been made to this trial as and when required but the coffeehas not been irrigated.

RESULTS

The coffee yield results for five seasons (1956/57)—(1960/61) are summarized in Table 3 and 4.

TABLE 3.

The effect of interplanted bananas on the yield of mature *Arabica* coffee (Cwt. of clean coffee per acre per annum).

Year	*Interplanter Bananas* B_0	B_1
1956	11.88 (8)	11.51
1957	6.42	3.82
1958	11.24	6.20
1959	13.49	8.65
1960	8.03	4.91
Mean	10.21 (40)	7.03

NOTES 1. Least Significant Difference of Marginal Mean=1.71x; 2.52xx.
Least Significant Difference of Body of Table=1.29x; 1.70xx; 2.17xxx.

The effect of interplanting bananas (Table 3) in this mature coffee has been to significantly reduce the crop yield over the four years following establishment.

Interplanting bananas in June 1956 did not reduce the crop yield significantly in the 1956/57 season as might be expected; thereafter the effect in each of the next four seasons was substantial. The cumulative totals for these four seasons were $B^0=39.18$ and $B^1=23.58$, a total reduction of 15.60 cwts. of clean coffee per acre.

TABLE 4.

Relationship between pruning system and interplanted bananas. (Cwt. of clean coffee per acre per annum; mean of 5 seasons).

Interplanted Bananas	P_0	P_1	P_2	P_3	*Mean*
B_0	11.68	9.67	7.74	11.75	10.21
B_1	8.04	6.81	5.02	8.32	7.03
Mean	9.86	8.24	6.38	9.99	

NOTES 1. Least Significant Difference Pruning Means=1.17x; 1.57xx; 2.06xxx.
Least Significant Difference Body of Table=1.66x; 2.22xx; 2.92xxx.
2. Coefficient of Variation=30.6%.

In all the four pruning systems, interplanting bananas has significantly reduced the yields in a similar manner; there is no interaction between pruning methods and bananas i.e. no differential effects are observed.

The similarity in mean yield between treatments P^0 and P^3 reveals the compensation for loss of premaries that can occur in terms of crop yield under the conditions of this experiment. The drastic reduction of bearing wood in treatments P^1 and P^2 with consequent crop reducton at least in the first crop season, has not yet been made up in later yields. However, it seems possible that after a few more seasons, the yield of the multiple stem pruning treament, P^1, will catch up with P^0 and P^3.

The system of pruning the P^3 treatment is much simpler than conventional single stem and this is one of several trials in which this Umbrella type of pruning system shows promise as a simple pruning method. More yields are necessary however, before any final conclusions can be drawn with regard to the pruning treatments.

GENERAL SUMMARY AND CONCLUSIONS.

A variety of evidence has been presented which shows that bananas interplanted in either young or mature *Arabica* coffee, unshaded or lightly shaded, reduces crop yields to a substantial degree under conditions at the Coffee Research Station, Lyamungu and over a part of the main coffee area on Mount Kilimanjaro. No attempt has been made to evaluate the economics of mixed coffee/banana plantings and it has been assumed that the primary objective is the production of high yields of quality coffee.

It is not possible from these trials to define the reason(s) for this effect on coffee yield; more particularly, in none of these trials is it possible to separate the shade influence of the bananas on coffee yields from other factors which may

be involved in yield depression, because no comparative shade treatment, either artificial or natural i.e. other tree shade, was included in any of the trials.

Nevertheless there are parts of Tanganyika where bananas are interplanted in coffee fields but where shade is not a necessary condition for good coffee growing nor is the banana a major subsistance crop. There are also areas where sufficient land exists for the bananas to be planted separately as a pure stand.

It is concluded therefore that where coffee is the primary cash crop and any or all of the conditions outlined in the previous paragraph exist, bananas should on no account be interplanted with *Arabica* coffee. Furthermore, in areas where shade is a necessary cultural practice for coffee growing but where bananas are not an important crop and/or there is sufficient land available to grow pure stands, the evidence presented here reinforces our advice that bananas are not a good natural shade for coffee and less competitive alternatives should be used.

REFERENCES.

1. Sykes(A. Coffee/Banana Survey—Moshi District 1959. Report in Department of Agriculture Files

HERBICIDE EXPERIMENTS IN ARABICA COFFEE, 1960—61

By S. D. HOCOMBE, Botanist
Tropical Pesticides Research Institute, Arusha, Tanganyika
(Miscellaneous Report No. 308. November, 1961)

INTRODUCTION

Recent work on the costs of mechanical weeding in East African plantations of arabica coffee (*Coffea arabica*) suggests that, for general weed control in the established crop, chemical methods are seldom an economic alternative to mechanical weeding. However, there are a number of special situations in which chemical weed control has the advantage of achieving results which cannot be obtained by other methods; the control of couch (*Digitaria scalarum*) with dalapon (sodium 2, 2-dichloropropionate) is an example. It seems likely that it may also be economic, or nearly economic, to use chemical weed control as a substitute for hand weeding during the early stages of crop establishment.

Of the two experiments described below the first was concerned with the control of purple nutgrass (Cyperus rotundus), a weed which is as difficult to control by mechanical means as couch, and which frequently becomes very dense after the successful chemical de-couching of coffee. The second experiment aimed at discovering a suitable persistent herbicide to control weeds on the planting square, or 'cova', during the early stages of coffee establishment. This square is too close to the young trees to be reached by rotavators and similar implements, and is normally hand weeded at frequent intervals.

CYPERUS ROTUNDUS

For the control of nutgrass only one herbicide, EPTC (ethyl-NN-dipropyl-thiolcarbamate) appeared, from previous work, to be worth testing. A liquid and a granular formulation were compared. The herbicide was applied to 1/400th acre plots either with a knapsack sprayer, or, in the case of granules, by hand scattering. The herbicide was incorporated into the soil immediately after application with 'jembe' hoes working to a depth of 2½ inches. Each treatment was replicated three times, and the plots were re-treated after sixteen weeks, when the hoes worked to a depth of 7 inches.

The nutgrass was growing vigorously at each treatment date. The soil, a brown volcanic loam, was dry to a depth of 2 inches at the time of each treatment, and remained dry during most of the experiment, since rainfall was abnormally low.

The nutgrass shoot density was determined at intervals after treatment using a randomly thrown quadrat, and to prevent any reduction in shoot density due to competition with other weed species these were removed by hand at each counting date. The results of this trail are summarised in Table 1.

TABLE 1.

Effect of liquid and granular EPTC formulations on *C. rotundus* shoot density. Experiment started 22.8.60.

Treatment		*Pre-spray count. Shoots per sq. ft.*	*Shoot density as % of pre-spray count at various times (weeks) after treatment*							
Herbicide	*Dose (lb/ac)*		2w	6w	11w	16w	18w	25w	31w	36w
EPTC (L)	4.0	3.5	44	81	99	294	14	52	266	475
EPTC (L)	8.0	2.5	58	83	122	228	20	12	132	424
EPTC (G)	4.0	6.1	35	48	55	127	7	8	62	244
EPTC (G)	8.0	4.8	41	51	47	79	4	2	17	117
Control	—	4.8	81	103	196	419	65	295	395	512

(L) = liquid fomulation, (G) = granular formulation. Double line indicates date of re-treatment, which was made immediately after the 16 week count.

It appears from the results that the granular formulation of EPTC is more effective against *C. rotundus* than the liquid formulation at equivalent doses, and that better results can probably be expected when the tools for the incorporation of the herbicide work to a depth of 7 inches than when they work only to $2\frac{1}{2}$ inches. While EPTC obviously gave considerably better results than cultivation alone (control plots) the re-establishment of the nutgrass population would have been more rapid if more rain had fallen during the course of the trial.

Susceptibility tests suggest that neither young nor mature coffee trees are effected by EPTC at doses of up to 8 lb. per acre, although there is, as yet, no evidence concerning its effect on crop flavour.

For weed control on the seedling planting square several herbicides were applied with a knapsack sprayer at a volume rate of 50 gallons per acre. The planting holes had been dug out, refilled, levelled and clean weeded just before spraying. Each planting hole was one yard square, and two days after spraying the coffee seedlings were planted by opening out a small hole with a spade, inserting the seedling, and tamping the soil back into position. Each treatment was replicated five times.

Six herbicides were tested: monuron (N-(p-chlorphenyl)-N'N'-dimethylurea); diuron (N-(3, 4-dichlorphenyl)-N'N'- dimethylurea); fenuron (NN-dimethyl-N' -phenylurea); 'Alipur', a mixture of 3.3 parts OMU (N-cyclooctyl-N'N' -dimethylurea) and 2.2. parts BIPC (Butinol-N-(3-chlorphenyl) carbamate); simazine (2-chloro-4, 6-*bis* (ethylamino)-1,3,5-triazine), and atrazine (2-chloro-4 ethylamino-6-isopropylamino-1,3,5-triazine).

The soil, again a brown volcanic loam, was moist on the surface at the time of treatment, and conditions for weed growth remained excellent throughout the trial. In the lower soil layers the moisture content was low.

A subjective scoring system was used in describing subsequent weed growth on the plots, a score of 5 indicating no weeds, 4 'acceptable' control, 3 a moderate weed cover, 2 a heavy cover, 1 a very heavy cover, and 0 a solid stand of weeds which completely covered the soil. The effects of the treatments on weed growth are summarised in Table 2; the dominant weed species were *Nicandra physaloides, Galinsoga parviflora and Commelina benghalensis.* There were few grass weeds.

Weed establishment in the soil which had been disturbed by planting was slightly more rapid than on the rest of the plots, but this was only a minor

effect. The results suggest that, under conditions ideal for weed growth, simazine, atrazine or diuron at doses of 3 to 4 lb. per acre (active) can give adequate control for about ten weeks. The cost of herbicide, for simazine, would be about 5 cents per planting square, or Shs. 25/- per acre for a 9 foot by 9 foot planting.

The establishment of the coffee seedlings was poor throughout the experiment, and also in the adjacent untreated areas. However, there was no evidence that the herbicides affected the coffee seedlings in any way.

TABLE 2.

Mean subjective weed density scores at intervals after spraying, experiment started 3.6.61.

Treatment		*Mean weed density scores at various times (weeks) after treatment*			
Herbicide	*Dose (lb/ac) active*	2w	4w	7w	11½w
Monuron	1.5	.9	3.7	3.5	1.8
,,	3.0	4.0	4.1	3.8	2.4
,,	4.5	4.1	4.5	3.8	2.9
Diuron	1.5	4.3	4.3	4.1	3.1
,,	3.0	4.4	4.6	4.2	3.1
,,	4.5	4.6	4.7	4.5	3.5
Fenuron	1.5	3.9	3.7	2.8	0.8
,,	3.0	3.9	3.8	2.9	1.3
,,	4.5	3.9	3.7	3.0	1.7
'Alipur'	2.0*	4.1	3.7	2.8	1.1
,,	4.0*	4.0	3.6	2.7	0.9
,,	6.0*	4.1	3.9	3.3	1.1
Simazine	1.5	4.3	4.5	3.9	3.0
,,	3.0	4.2	4.5	4.6	3.6
,,	4.5	4.7	4.7	4.3	3.6
Atrazine	1.5	4.2	4.3	4.1	3.0
,,	3.0	4.6	4.7	4.4	3.8
,,	4.5	4.1	4.5	4.4	3.6
Control	—	3.5	2.9	1.6	0.2
,,	—	3.6	3.1	1.8	0.4

* Total dose of active ingredients.

ACKNOWLEDGMENTS

I am indebted to Mr. J. B. D. Robinson, Director of the Coffee Research Station, Lyamungu, for his assistance in arranging these trials.

INSECTICIDES IN COFFEE: A REVIEW OF PROGRESS SINCE 1957

By R. G. TAPLEY, Entomologist.

HISTORICAL REVIEW :

Insecticides have been used regularly in coffee during the past 30 years. The lime-sulphur preparations used for thrips control (*Diarthrothrips coffeae*) and sodium arsenite baits for Antestia control (*Antestiopsis lineaticollis*) gave way to DDT in 1948, and the impression gained was that DDT was the panacea for most, if not all, insect troubles. Antestia was controlled with unprecedented efficiency at a cost of less than 10/- per acre, even with low standards of spraying, and the new insecticide was equally remarkable in controlling thrips.

The first intimation that all was not well with DDT as a general purpose insecticide occurred in 1956 when massive doses of DDT failed to give any control of thrips at Oldeani and an apparent DDT resistance was also developing on the slopes of Mount Kilimanjaro (Tapley 1957).

DDT was replaced to some extent in 1957 when it was found that dieldrin gave equally good results against Antestia, and that it would also control DDT resistant thrips. Dieldrin was also very effective in controlling the White coffee-borer (*Anthores leuconotus*) and Coccid attending ants (*Pheidole punctulata*) when applied on the main stems.

However, during the last decade, other coffee pests have become economically important, Leaf-miner (*Leucoptera meyricki*) and Berry-moth (*Prophantis smaragdina*) being the most notable of these. Leaf-miner frequently defoliates trees during the hot season and it is not uncommon to see trees in flower which are almost bereft of leaf. Berry-moth often destroys a large proportion of the crop annually and losses as great as 20 / have become almost normal in many areas. Quite frequently, more than half of the cherry is destroyed.

The Problems:

There were, therefore, two problems that urgently needed attention at the Coffee Research Station. The first was to find ways and means of controlling the new pests. Insecticides appeared to provide the easiest means of doing this, and an insecticide screening programme was set under way. Secondly, and in the long term view more important, was to find out whether outbreaks of recent pests could be attributed to the use of the new insecticides. If so it should be possible to avoid further trouble of this nature.

I. INSECTICIDE SCREENING

Insecticide screening is the measurement of the killing power of available insecticides against specific pests. The insecticide which gives the best kill at the

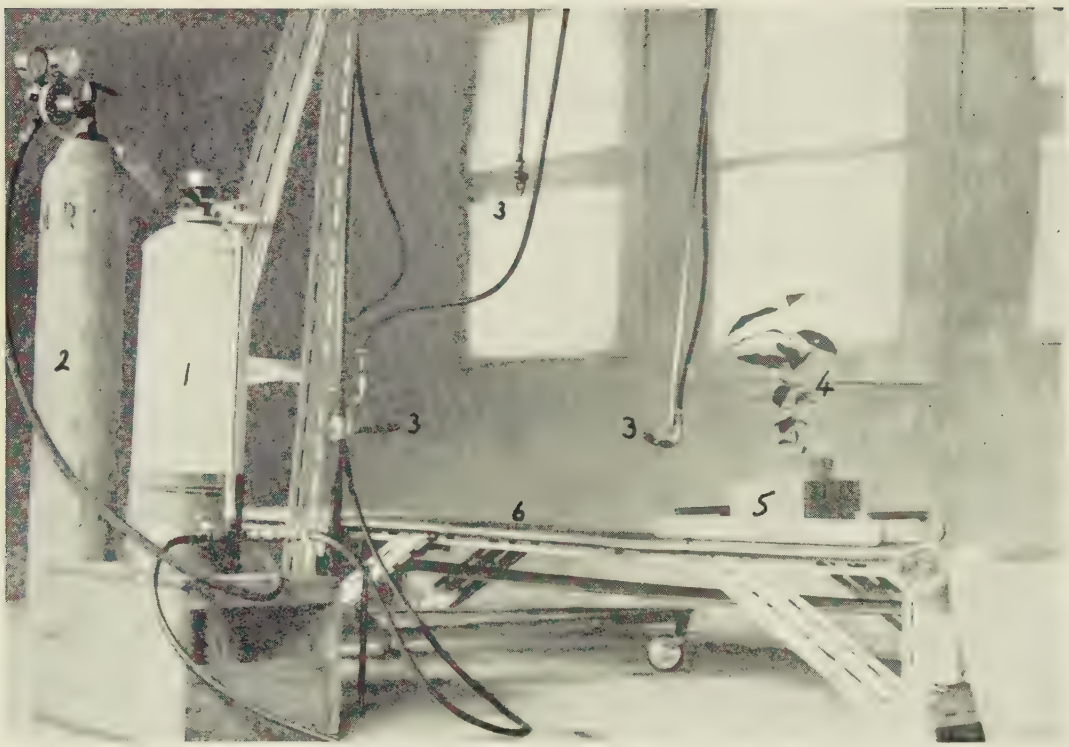


PLATE I.—This Laboratory Sprayer is used at the Coffee Research Station to spray potted coffee seedlings for insecticide tests. The insecticide under test is diluted appropriately and poured in the container (1) Compressed air (2) at 50 lbs. sq. in is used to force the insecticide through the three spray jests (3) The coffee plant (4) in a cradle (5) is carried on a variable speed moving belt (6) through the spray. A speedometer indicates the speed at which the seedling is moving in relation to the static spray jets. (Photo : ZNATOWICZ)

PLATE II.—The sprayed plants are immediately placed in the cages as shown here. Three pieces of glass and a piece of gauze in a metal frame make four side faces (each 2' x 1'), which are held upright and together by four wooden corner pieces and eight springs. The top of the cage is covered by cotton mosquito netting which is held in place by four pieces of wood which slip under the top four springs. Ten antestia adults are introduced into each cage before the spray has dried. Three plants are sprayed with each concentration of insecticide, so there is a total of 30 insects per level of insecticide. (Photo : ZNATOWICZ)

lowest cost, and is otherwise acceptable, is the one selected and recommended to farmers.

LEAF-MINER screening is carried out on the mining larvae in the field during epidemics. Each insecticide is sprayed on infested trees at 0.3%, 0.2%, 0.1%, 0.05%, 0.025% of active ingredient in water at the rate approx. 100 gall/acre. Twelve to fifteen trees are sprayed at each concentration. Two days after spraying 100 mined leaves are picked at random from the trees and taken to the laboratory where a count of living and dead larvae is made. First instar larvae are not included in the count as they cannot be exposed to view easily without being damaged. One hundred infested leaves can yield up to 600 larvae.

Unsprayed leaves are also examined to obtain the degree of mortality by natural factors, particularly parasite activity which may be as high as 20%. From the data obtained a graph of the probit mortality by log dosage can be obtained and, if the points fall approximately in a straight line, the test can be considered satisfactory.

As many insecticides as possible are sprayed in the shortest possible time on one site to make the tests as even as possible. Each insecticide is tested more than once, and those showing promise are tested subsequently on a larger scale, usually in acre blocks.

The results of some tests made are shown in Table 1.

ANTESTIA screening cannot be carried out in the field since the insecticides currently in use make it extremely difficult to find enough plots of coffee containing satisfactory populations of insects for tests. Therefore, all screening is carried out in the laboratory. Potted coffee seedlings are sprayed by a laboratory sprayer, (see Plate I.) and then placed in ventilated cages (see Plate II). Field collected Antestia are then placed on each sprayed tree. The numbers of dead and living antestia are counted after 48 hours or more exposure to the insecticide. Insecticides are applied at the equivalent of 3 lb., 2 lb., 1 lb., ½ lb. and ¼ lb. and no insecticide per acre. Thirty test insects are used per level of insecticide. Tests are usually repeated on a narrower range of concentrations if the first tests show promise. The results of tests are also summarized in Table I.

BERRY-MOTH. No satisfactory screening technique has yet been developed for this pest. Tests have shown that, in the field, all insecticides give a poor kill as soon as the coffee cherries are large enough to contain berry-moth larvae. An examination of infested nodes of cherry that had been sprayed with a flourescent chemical showed that none or very little of the insecticide sprayed from both hand and tractor powered pumps penetrated the webb and frass of the caterpillars around the cherries at the nodes. However, it was observed that parathion when used in leaf-miner and antestia control also kept berry-moth infestations in check if sprayed early enough during the season; it is the only insecticide tested to date that gives some control later in the season, but results tend to be erratic.

II. THE CAUSE OF OUTBREAKS OF LEAF-MINER AND BERRY-MOTH.

One of the most fruitful lines of investigation has been the effect of DDT and dieldrin on the natural enemies of Leaf-miners and Berry-moth. It was considered that these insecticides, while not particularly effective in destroying leaf-miner and berry-moth, would destroy the parasite populations of the two pests far more effectively.

TABLE 1.

Results of Tests against Coffee Pests. Insecticides are identified by the trade name applied by the manufacturer.

Insecticide	*Leaf-miner Larvae (Field Test)*	*Antestia adults (Laboratory Test)*
Aldrin	—	Good 0.4 lb.
Chlorothion	Poor	—
D.D.T.	—	Good 0.8 lb.
Delnav	Poor	Poor
Diazinon	Good 0.8 to 1.0 lb.	Moderate
Dibrom	Moderate*	—
Dieldrin	—	Good 0.25 lb.
Dipterex	Poor	Good
Dimecron	Poor	—
Endrin	—	Good
E P N	Poor	—
Gusathion	Erratic*	Moderate
Isochlorothion	Poor	Good
Kepone	Poor	—
Lebaycid	Moderate*	—
Malathion	Poor	Erratic 1 lb. to 1¼ lb.
Metasystox	Poor	Good
Metaisystox	Poor	Good
Nankor	Poor	—
Nuvan (DDVP)	Moderate*	—
Parathion (ethyl)	Good 0.4 lb.	Good 0.4 lb.
Parathion (methyl)	Good 0.4 lb.	Good 0.4 lb.
Phosdrin	Poor	—
P.P. 175	Poor	—
Rogor	Moderate	Good
Sevin	Poor	Moderate
Trithion	Poor	Poor
WL 1650	—	Good

* Further tests justified at earliest opportunity.

TERMS USED : (in Table 1).

GOOD : An economic control obtained with 1 lb. or less of active ingredient per acre. Where the weight is given this is the quantity of active ingredient required per acre to give an economic control as established by extensive field tests.

MODERATE : An economic control obtained at an estimated 2 lb. of active ingredient per acre.

POOR : An economic control not obtained at any concentration.

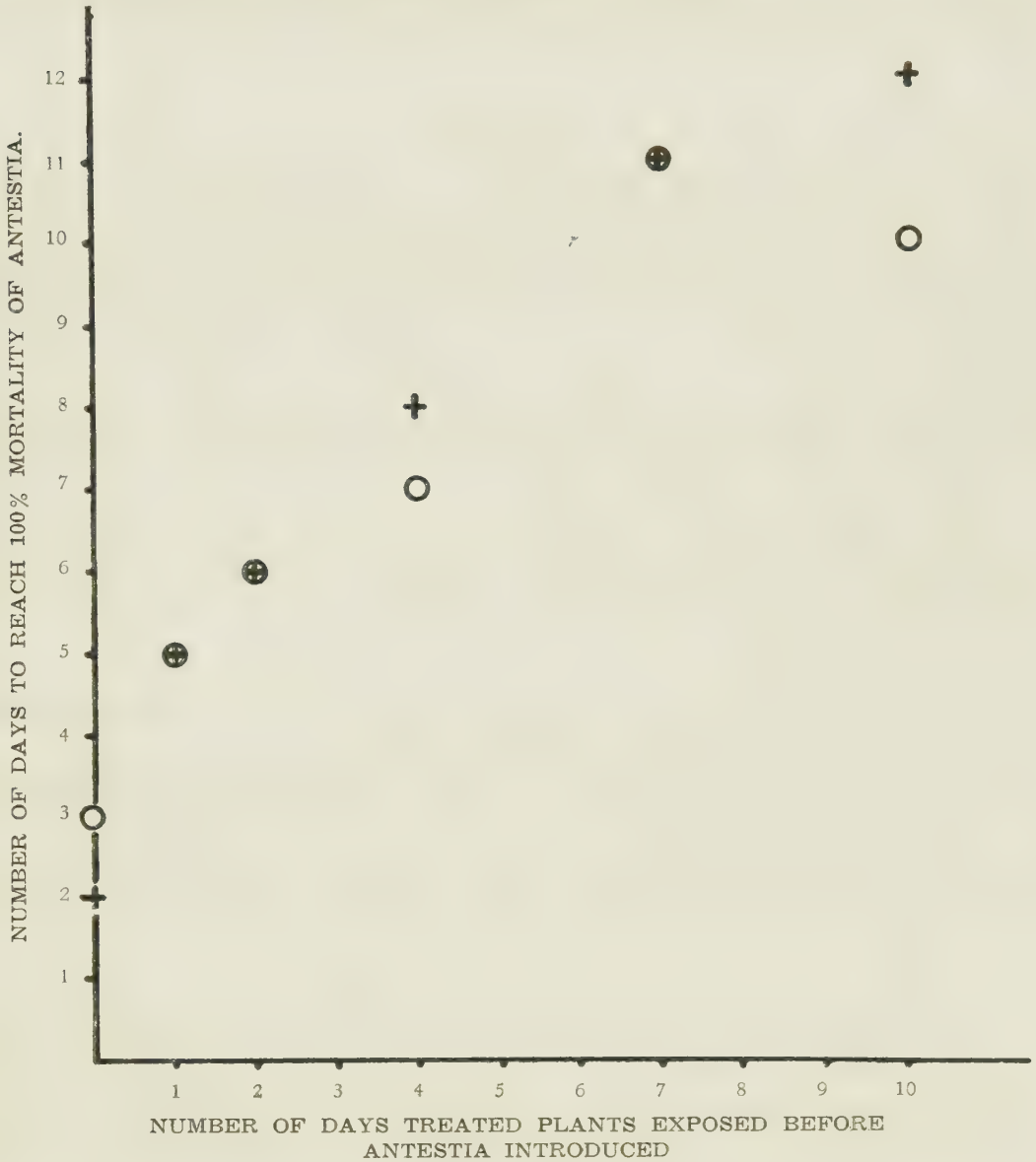
ERRATIC : Results vary from test to test.

Residual Activity of DDT and Dieldrin

During 1958 (Sleep 1958) showed that both DDT and dieldrin were extremely persistent on coffee leaves. Some 20 / of the original deposit of DDT could be found on a coffee leaves 23 days after spraying and a definite deposit could still be detected eight weeks after spraying. Dieldrin was also found to be highly persistent but slightly less so than DDT.

A number of tests were made in this laboratory on the biological effects of these insecticides on Antestia. A series of potted plants were sprayed by the laboratory sprayer described earlier which is designed to apply an even and reproduceable quantity of insecticide (See Plate I.). Some plants were placed in cages immediately after spraying, and Antestia were placed on them. Other plants were weathered in the field from 1 to 10 days, and then placed in cages with Antestia. The results of the experiment are shown in Fig. I., and they show quite clearly that sufficient DDT and dieldrin persisted on coffee leaves ten days after spraying

FIGURE I.—Graph showing the time (in days) that Weathered Deposits of DDT and Dieldrin on coffee plants take to give 100% mortality of Antestia.



to kill an Antestia population. While the deposit of insecticide immediately after spraying was sufficient to kill all the insects within two to three days, ten to eleven days of contact were necessary to destroy the population when the insecticide deposit was weathered from seven to ten days.

DISCUSSION :

Both DDT and dieldrin residues after 10 days exposure in the field are definitely insecticidal to Antestia, a comparatively large insect. It is, then, reasonable to assume that the residues are also toxic to many, if not all, of the species of Hymenoptera which are parasites on leaf-miners and berry-moth. These minute wasps, because of their interminable, restless seeking for prey are probably quicker to pick up a lethal dose from toxic residues than the comparatively quiescent Antestia.

These conclusions are supported in full by the studies reported in the previous Annual Report (Tapley, 1960). The continuation of this project on a much larger scale, in twenty acre blocks, has apparently given very similar results although the data has yet to be studied in detail.

The case against DDT and dieldrin as foliar sprays for Antestia and thrips control is sufficiently strong to justify their withdrawal from the spray programme, but the problem arises as to what insecticides should be used instead. It is easy to specify what is required of an insecticide, but the ideal insecticide for use in coffee probably does not yet exist.

What is required?

(1) The insecticide should be inherently toxic to all of the three main pests viz. Antestia, Leaf-miner and Berry-moth.

(2) It should be inherently less toxic to the parasite populations. Perhaps this is too much to expect, but at least the insecticide should allow relatively more of the parasites to survive spray treatments than of the pests.

(3) The cost must be moderate. It may be difficult to persuade African Co-operatives to spend more than 10/- per acre with the present low standards of husbandry, and declining prices.

(4) Since most trees are sprayed by hand operated sprayers the insecticide should have a low level of mammalian toxicity.

The parathions (both the ethyl and methyl forms) are the only insecticides that meet most of the requirements. They control Antestia, Leaf-miner and Berry-moth at a cost of about 12/- per acre per application. Tests with methyl parathion against Antestia adults in the laboratory have shown that the residual life is extremely short, no mortality was recorded when the insects were introduced on plants sprayed 24 hours previously.

There are strong indications, although the available data has yet to be studied in detail, that the parathions destroy leaf-miners more efficiently than the parasite populations. It would seem that any parasite that is in the pupal stage at the time of spraying has an excellent chance of survival, especially if the insect emerges from the pupal case several days after spraying.

While it was shown that parathion could be used safely on the larger farms (Tapley and Znatowicz, 1960) it was considered that parathion was too dangerous

to be recommended to the peasant farmers who number about 40,000 on Kilimanjaro alone.

Diazinon would almost certainly be satisfactory for use on peasant farms, but the cost of 50/- per acre per application makes its use prohibitive.

As a temporary measure it was decided to recommend aldrin wettable powder where antestia control only was required, and where parathion could not be used safely. Aldrin is less persistent on coffee leaves than DDT and dieldrin (Sleep K.C. 1958) and approximately the same price. Malathion which is commonly used elsewhere in East Africa could not be recommended since it costs about 20/- per acre and results tend to be erratic in Tanganyika.

For the peasant farmer in the near future the best that can be hoped for is a moderately priced insecticide that will destroy Antestia, give a moderate kill of Leaf-miner and possibly also Berry-moth, and yet not antagonise the parasite populations too much. This in the long run may be satisfactory where the standards of cultural practices are low and when, in any case, Leaf-miner and Berry-moth control are less important. When Leaf-rust control is attempted and the standard of pruning improved then other more suitable insecticides may be available to the farmer. By this time leaf-miner and berry-moth may again be of occasional importance as they were, apparently, prior to the discovery of DDT as an insecticide.

ACKNOWLEDGEMENTS

The laboratory sprayer in Plate I, was made by Mr. George Poulton, recently of the Tropical Pesticides Research Unit at Arusha.

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NATURAL MORTALITY OF EGGS AND EARLY INSTARS OF LEAF MINER

By R. G TAPLEY, Entomologist

Observations on all mortality factors of leaf-miner are at present being made as a basis for a population dynamics study at a later date. From this it is hoped to gain an understanding of the factors which give rise to Leaf-miner outbreaks and it may then be possible to find the means of preventing their occurrence.

During the past year it has been shown that there is a hitherto undescribed mortality of first instar larvae, either before or after eclosion from the egg, of both *Leucoptera meyricki* and *L. caffeina*. Later instar larvae have also been dying from no apparent cause. This condition is believed not to be new in Tanganyika since Notley (1955), giving an account of his work prior to 1939, wrote "at times, however, there appears to be a high mortality amongst first instar larvae, the cause of which is unknown." As he made no further reference to the condition it is concluded that he attached no great importance to it.

Jardine et al (1941) in Puerto Rico found that under "favourable greenhouse conditions" most of the leaf-miner caterpillars (presumably of *L. coffeella*) either failed to penetrate the leaf or died soon after eating portions of the tissue. They considered the failure of the caterpillar to infest leaves to be due to the tree developing an immunity to the insect.

In Tanganyika it would appear that some first instar larvae (or embryos) die before eclosion from the egg commences, so that this suggests that the mortality is not due entirely to the plant resistance. More often the larvae die (a) while entering the leaf tissue or (b) soon after it has left the egg completely and is established in its own mine. In some few cases second and later instars are observed to have died in a similar manner.

The cause or causes of death are not known. Eggs containing dead embryos have been observed in some cases to contain fungal hyphae and bacteria, but these are probably of secondary importance only.

TWO SIMPLE EXPERIMENTS

It was noted that, during the latter months of 1961, expected leaf-miner outbreaks had generally not materialised. This has been attributed to the exceptionally heavy and widespread rains which normally do not occur during these months with such intensity. The question arose as to whether these wet, humid conditions influenced the mortality of first instar larvae. Two simple experiments were carried out to find out whether there was any indication of an association of wet conditions with high larval mortality.

Experiment I.

Caged *L. meyricki* moths oviposited on ten potted 'arabica' coffee plants in the insectary. Five of these plants (selected at random) were then sprayed with fine droplets of water and placed in a humid chamber for six days. Occasionally the trees were resprayed and it is believed that the upper surface of the leaves were continuously wet during the whole period. When these plants were removed from the humid chamber they were placed on a bench for several days until they were examined. The other five potted plants were left on the insectary bench for the whole period and the leaves were not wet at any time.

The results of this experiment are summarised in Table 1.

PLATE I.—Showing eggs of *L. coffeina*, almost certainly laid at one time by one moth. Three eggs (marked 'A') hatched successfully and the larvae remained healthy. One larva 'B' died while entering the leaf tissue, and in six others 'C' (three not shown) the larvae died before eclosion commenced. (Photo : ZNATOWICZ).

EXPERIMENT II.

In this experiment cut branches were used. The stems were cut under-water and placed in specimen tubes containing water. The branches were trimmed so that four mature leaves remained on each. The water in the specimen tubes was topped up as required, and in this way the leaves remained fresh for several weeks. These branches were placed in cages containing leaf-miner moths for two days, and, after oviposition, half of the branches were then placed on an insectary bench while the other half of the branches were placed in large glass storage bottles and closed with polythene. Periodically the polythene was removed for a few minutes to allow fresh air into the jars. Transpiration apparently continued normally and water soon condensed inside the jars. Presumably the humidity was near to 100% most of the time, but at no time was a film or droplet of water observed on the leaves. The plants were not sprayed with water as in Experiment I. After approximately two weeks the leaves were examined for living and dead miners and the results are shown in Table 2.

CONCLUSION :

There would certainly appear to be a strong association of high larval mortality with wet conditions (Exp. I.). It also appears that humid conditions of the surrounding atmosphere alone are not responsible for very high mortality figures (Exp. II). The results justify a closer study of the relationship of wet coiditions with mortality in the near future.

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Report on the Agricultural Experimental Stations, 1940, pp. 116—117.
Notley, F. B., 1955, Bulletin of Entomological Research, V, 46, 903.

TABLE 1.

Showing the fate of *L. meyricki* eggs oviposited on Wet and Dry plants in the Insectary.

Conditions	*No. of Eggs on five Plants*	*Infertile or Empty Eggs*	*No. of Eggs Containing Dead Embryos*	*No. of Larvae Dead during Eclosion*	*No. of First Instars Dead in Mines*	*No. Dead Later Instars*	*No. Larvae Survived*
'Dry' Plants	308	0	8	16	41	22	221
'Wet' Plants	181	5	106	61	8	0	1

TABLE 2.

Showing the fate of *L. meyricki* eggs oviposited on leaves stored in Glass jars (Humid conditions) and on the bench in the insectary.

Conditions	*No. of Eggs*	*Embryo Dead in Egg*	*Died First Instar*	*Died Later Instars*	*No of Surviving Larvae*
'Dry' leaves	781	125	35	37	584
Leave in Glass Jars 'Humid'	784	94	58	31	601

OBSERVATIONS ON UNKNOWN DIEBACK OF COFFEE PRIOR TO AND DURING 1961

By D. A. BURDEKIN, Plant Pathologist.

A condition now referred to as Unknown Dieback of coffee has been recognized at the Coffee Research Station, Lyamungu since 1956. This condition has caused the death or severe die back of many hundreds of trees since that time.

A number of observations were made prior to 1961 when a detailed study of the condition was undertaken. These observations were restricted to coffee on the Research Station and may be summarized as follows :

1. Trees were initially and most severely affected in their third year in the field. This was generally when the coffee bore its first heavy crop.
2. Trees affected were all unshaded.
3. The affected area on the Research Station was old coffee land.
4. The condition could be alleviated and the trees kept alive by stripping the crop prior to ripening when the first visible foliar symptoms were observed.
5. Affected trees always seemed to be bearing a heavy crop.

The external symptoms of the condition were studied and these may be classified as follows :—

(i) A wilt along bearing primaries.

(ii) A yellowing of leaves on such primaries not resembling any known nutrient deficiency.

(iii) Together with symptoms (i) and (ii), blackened stipules often occur several nodes back from the tip of the primary.

(iv) Death of leaves tends to start several nodes back from the tip and spreads in both directions.

(v) There is a tendency for the primaries to show "goose necking" at a point where the nodes are close together.

Early in 1961, the Unknown Dieback condition was identified outside the Coffee Research Station, Lyamungu, on two estates in the Northern Province of Tanganyika. As a result of this observation a determined effort was made to obtain further information on this serious condition of coffee.

A survey was carried out to investigate the extent to which the condition was present on Estates and in African areas. A more detailed survey was also undertaken on the Research Station itself.

A total of twenty four estates were visited in the following parts of the Northern Province :

Arusha
Monduli
Usa
Sanya Juu
Moshi

Six widely scattered estates were found to be affected. Managers of all estates visited were asked for details of their various cultural treatments. All affected estates were found to have a satisfactory standard of management. In common with the Coffee Research Station, these estates achieve good yields per acre and it appears that this condition is one affecting high yielding trees in their early years of bearing.

As the survey progressed it became obvious that visual symptoms of affected trees on estates were variable. Thus a more diagnostic symptom was required to be certain that Unknown Dieback was present. Such symptoms were discovered and are described later.

A survey of African areas was carried out in collaboration with the Agricultural Department in Moshi and Arusha. No deaths or diebacks due to the condition were found.

As this condition has been found only on high yielding coffee, it is not expected that symptoms will be widespread in these African areas where coffee is usually grown under heavy banana and indigenous forest tree shade.

A detailed survey of the Coffee Research Station was carried out in July 1961. At first, the survey was based on visual symptoms, but later, suspected areas were investigated in more detail.

On the basis of visual symptoms, the following observations were made :—

1. Seven experiments were affected prior to 1961.
2. Seven more experiments were affected during 1961.
3. Six further experiments showed yellowing trees which may have been the result of Unknown Dieback.
4. Young Coffee, two years and less in the field showed no visual symptoms.
5. Older coffee on the Station (15 years and more) showed no visual symptoms.

As a result of a more detailed examination (described later) of suspected areas (para 3 above) and young coffee (para 4 above) the following areas were also found to be affected :—

6. Two of the Coffee Research Station nursery sites.
7. Coffee in experiments planted out one or two years previously.
8. Two experiments classified in para 3 above.

The visual symptoms of Unknown Dieback have already been described and it has been suggested that such symptoms are not always sufficient to give a definite diagnosis.

A more detailed study was therefore made of affected coffee trees. The more interesting results were achieved by an examination of the roots and the following observations were made :—

1. Some of the roots, in particular the deeper ones showed a brown flecking or streaking when cut lengthways.
2. On microscopic examination, these brown flecks proved to be small pockets of gum in the vascular tracts of the root. Such a blockage in the vascular system may be responsible for the wilting symptoms already described for Unknown Dieback.

3. Tests were undertaken to determine whether a fungus was present in the roots. These showed that a fungus was only present in small roots, less than $\frac{1}{4}$" in diameter. Various fungi were isolated and attempts are now in progress to reinfect coffee.

4. In order to test whether these fungi could produce wilting in coffee they were grown in a liquid medium. The medium was filtered and cut shoots were dipped into the filtrate to test for the presence of a wilting agent. Two fungi regularly isolated gave a positive wilting test.

All estates suspected of having Unknown Dieback and a number of experiments on the Research Station were investigated under the four headings :—

1. Brown Flecking.
2. Presence of Gum pockets.
3. Fungal Isolation.
4. Wilt Test.

SUMMARY

1. Diagnostic symptoms, both visual and microscopic, have been defined and it will now be possible to identify the condition in any suspected outbreak.
2. Surveys were carried out, based on a detailed symptom picture, to assess the distribution of the condition.
3. The survey of Estates and African coffee has shown that Unknown Dieback is present on six estates outside the Coffee Research Station.
4. The survey on the Coffee Research Station has indicated that Unknown Dieback can reach serious proportions during the first five years in the life of unshaded coffee.
5. Microscopic symptoms of the condition have been found in the nursery at the Coffee Research Station.

This is an observational report on Unknown Dieback and further research is being actively pursued.

THE ESTABLISHMENT OF ROBUSTA COFFEE ON INFERTILE "RWEYA" SOILS IN BUKOBA DISTRICT

By H. W. MITCHELL, Agronomist, and J. N. AUCKLAND, Agronomist

INTRODUCTION

The climate of the lake littoral area of Bukoba district is well suited to the cultivation of robusta coffee, *Coffea canephora*. Temperatures are warm and equable and rainfall average 60—80" per annum and is well distributed.

The soils of the area are variable in their productivity. The more fertile areas, known locally as 'Bibanja' land, are intensively cropped with robusta coffee, bananas and annual food crops, whilst the less fertile areas, known locally as "Rweya" land, are largely under grass. The soils of both 'Bibanja' and 'Rweya' lands are derived from the Bukoba Sandstone, are light textured and free draining. They have a high organic matter content but low available phosphate, potash and calcium contents. The 'Bibanja' soils are of similar type but differ considerably in their chemical composition, as may be seen from the analyses below.

TABLE 1.

Soil Analysis of 'Rweya' grassland

	Depth in inches						
	0–6	6–12	12–24	24–36	36–48	48–60	60–72
p.H.	4.8	5.0	4.6	4.4	4.4	5.0	4.6
Exchangeable Ca.me/100 g.	0.6	0.8	0.8	0.6	0.8	0.8	0.7
P. p.p.m.	<10	<10	18	42	46	36	14
Organic Carbon %	4.90	3.92	1.79	0.97	0.78	0.68	0.78
N. %	0.35						
C/N Ratio	14.0						
Exchangeable K.me/100 g.	0.10						
Exchangeable Mg.me/100 g.	0.17						

Soil Analysis of 'Bibanja' soil, Maruku.

	Depth in inches						
	0–6	6–12	12–24	24–36	36–48	48–60	60–72
p.H.	5.4	5.0	4.8	4.5	4.5	4.6	4.7
Exchangeable Ca.me/100 g.	3.8	1.3	0.9	0.6	0.9	2.1	1.9
P. p.p.m.	28	28	34	26	36	56	46
Organic Carbon %	2.66	2.14	1.29	0.83	0.73	0.72	0.69
N. %	0.34						
C/N Ratio	7.8						
Exchangeable K.me/100 g.	0.17						
Exchangeable Mg.me/100 g.	0.61						

Milne surmises that the area was once covered by high rain forest but that this was cleared by man for cultivation. On the more fertile areas permanent settlement developed whilst the less fertile areas were abandoned as they became exhausted through cropping and leaching. (1) Crops of finger millet, *Eleusine coracana*, and bambarra nuts, *Voiandzeia subterranea*, are grown on the 'Rweya' grassland but yields are low. A single crop exhausts the land, which is allowed

to revert to grassland and is rested for about six years before being cropped again.

As a result of population increase it is necessary for people either to migrate to other areas or else to develop permanent settlements on the 'Rweya' grasslands. Cattle manure is used to establish bananas and coffee but this method of rehabilitating the grassland is limited by the shortage of this material. The reasons for this are that the pasture is extremely deficient in protein and minerals and as a result the cattle make very poor growth and are rather infertile. East Coast Fever is also endemic in the area and causes heavy calf mortality.

These problems are being investigated at the Coffee Experimental Station, Maruku, which is situated on 'Rweya' grassland soil about 8 miles south of Bukoba. Soil fertility invesctigations are being undertaken together with a programme of livestock and pasture improvement (2). Establishment trials are being carried out on coffee, bananas and annual food crops and also on possible alternative cash crops such as tea and tropical pines.

Early establishment trials with robusta coffee showed that only the seedlings planted with farmyard manure grow at all well. Seedlings planted without manure or fertilizer turned yellow and made no growth whilst those treated with nitrogen, phosphate and potash, singly or in all combinations, all died, probably because the fertilizer applications were too heavy. In 1956 it was decided that further establishment trials should be started.

THE TRIAL

Experiment MAR. 5 was planted at the Coffee Experimental Station, Maruku in November 1956 with the object of investigating the effect of farmyard manure, lime and artificial fertilizers for establishing robusta coffee on the infertile grassland soils.

The experiment is off a factorial 3 x 3 x 2 design, unconfounded, with two replications of 6 tree plots. The coffee was planted at 10' x 10' square spacing and a complete cover of grass mulch has been maintained. The trees were brought up on one stem without capping and will be converted to four stems in the second cycle, after five years.

The treatments are as follows :—

Farmyard manure :—

D_0 Nil.

D_1 20 lbs. in planting hole (one debe)

D_2 40 lbs. in planting hole (two debes).

Lime :—

L_0 Nil.

L_1 20 cwt. ground limestone per acre at planting time.

Fertilizers :—

F_0 Nil.

F_1 Basal dressing of N.P. K at planting time at the following rate per acre :— 2 cwt. ammonium sulphate, 2 cwt. double superphosphate, 1 cwt. muriate of potash.

F_2 Basal dressing as in F_1 above plus topdressings at the above rate per annum split into three applications which were applied in November, March and July.

The treatments were applied in the following manner. The farmyard manure was mixed with topsoil in the planting holes a month before the seedlings were

planted. The ground limestone was evenly spread over all the ground within three feet radius of the centre of the planting hole and was dug in and thoroughly mixed with the topsoil. The basal dressing of fertilizer was spread in a band around the planting hole between 6 inches and 2 feet from the centre of the hole, and was lightly dug into the topsoil. Fertilizer top dressings commenced in March 1957 and these were applied underneath the mulch in a ring around the coffee seedling on the drip line.

GROWTH RESPONSES

Height measurements were made on all seedlings at planting time and one and two years after planting.

Lime had no significant effect on growth over the first two years and is not shown in the following table, which shows the effect of farmyard manure and fertilizers.

TABLE 2.

The effect of farmyard manure on growth of seedlings one and two years after planting out. Average increase in height in inches per seedling.

One Year Nov. 1956-Nov. 1957.		F_0	F_1	F_2	Mean
	D_0	13.0	11.0	13.2	12.4
	D_1	13.5	15.9	18.0	15.8
	D_2	18.1	18.1	19.8	18.7
	Mean	14.9	15.0	17.0	15.6

	S.E.	L.S.D. (P=0.05)
Marginal means	1.08	3.22
Body of the table	1.81	5.40

Two Years Nov. 1956-Nov. 1958.		F_0	F_1	F_2	Mean
	D_0	26.9	23.9	28.3	26.4
	D_1	30.4	33.0	33.0	30.3
	D_2	32.4	32.0	37.0	33.8
	Mean	28.9	28.8	32.8	30.2

	S.E.	L. S. D. (=0.05)
Marginal means	1.30	3.88
Body of the table	2.26	6.74

In the first year farmyard manure increased growth by 27% when applied at 20 lbs. per tree and by 51% when applied at 40 lbs. per tree. The growth response was less marked in the second year, the overall growth increases for the two year period being 15% with 20 lbs. per tree and 28% with 40 lbs. per tree.

The basal dressing of fertilizer had no significant effect. Fertilizer top dressings gave an increase of growth which was not significant in the first year but was significant over the two years period.

YIELD RESPONSES

The trees bore a light crop in the 1958-59 season, which was their third year in the field, and a full crop in the 1959-60 season and the 1960-61 season. Plot yields were recorded as fresh cherry and converted to clean coffee by using an average outurn figure of 25%. The yields for the three years are shown in Table 3, together with the average yields for the three year period.

TABLE 3

Yields of coffee in lbs. per acre of clean coffee.

A. First crop 1958-59

	L_0	No lime			L_1	20 cwt/acre lime		
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
D_0	—	0.01	0.40	0.13	0.21	0.13	0.55	0.29
D_1	0.28	0.62	0.96	0.62	0.15	0.34	1.59	0.70
D_2	1.45	1.20	1.88	1.51	0.85	1.05	2.11	1.34
Mean	0.57	0.61	1.08	0.75	0.40	0.51	1.39	0.78

B. Second crop 1959-60

	L_0				L_1			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
D_0	2.16	1.29	4.73	2.72	4.64	3.21	4.90	4.25
D_1	3.76	4.01	4.68	4.13	4.21	3.59	7.53	5.11
D_2	6.34	6.54	8.30	7.06	3.96	3.74	8.28	5.33
Mean	4.07	3.95	5.90	4.64	4.28	3.51	6.90	4.89

C. Third crop 1960-61

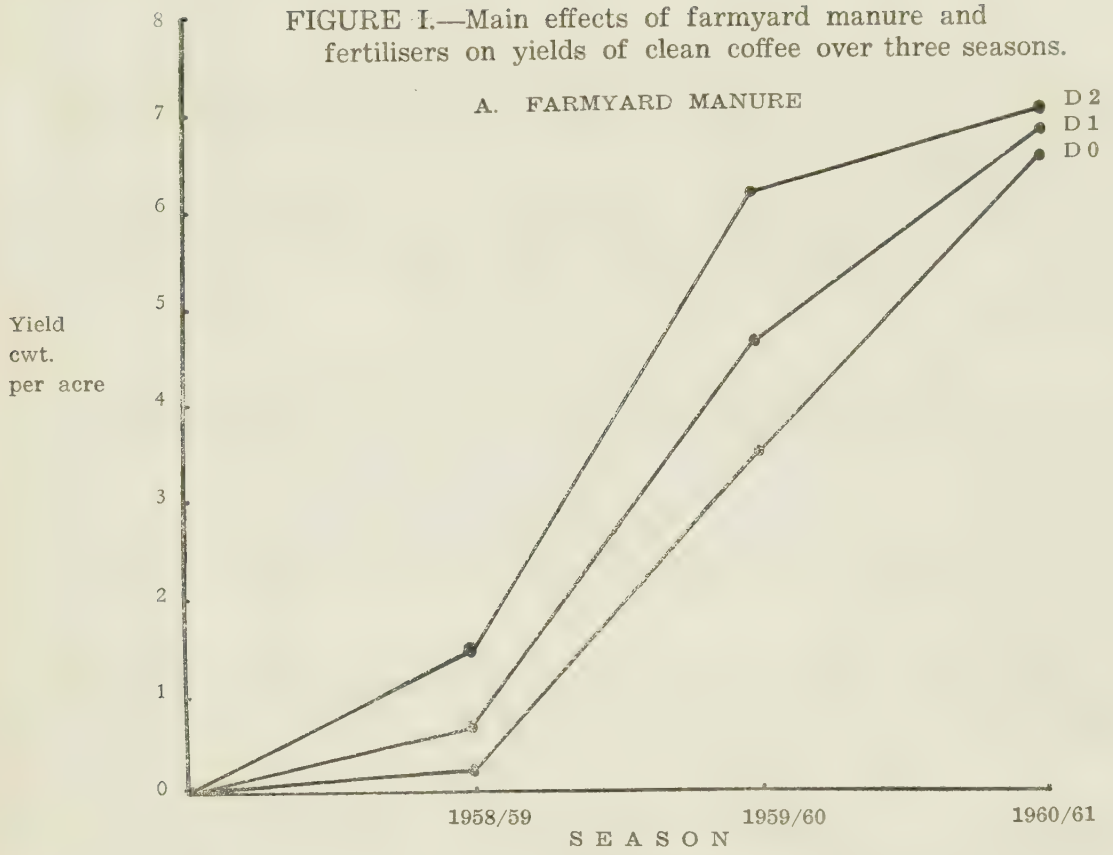
	L_0				L_1			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
D_0	6.32	6.58	6.73	6.54	6.83	5.17	7.18	6.39
D_1	6.16	7.32	5.47	6.32	6.67	5.74	8.89	7.10
D_2	5.96	8.54	7.41	7.30	3.97	7.54	8.12	6.54
Mean	6.14	7.48	6.54	6.72	5.82	6.15	8.06	6.68

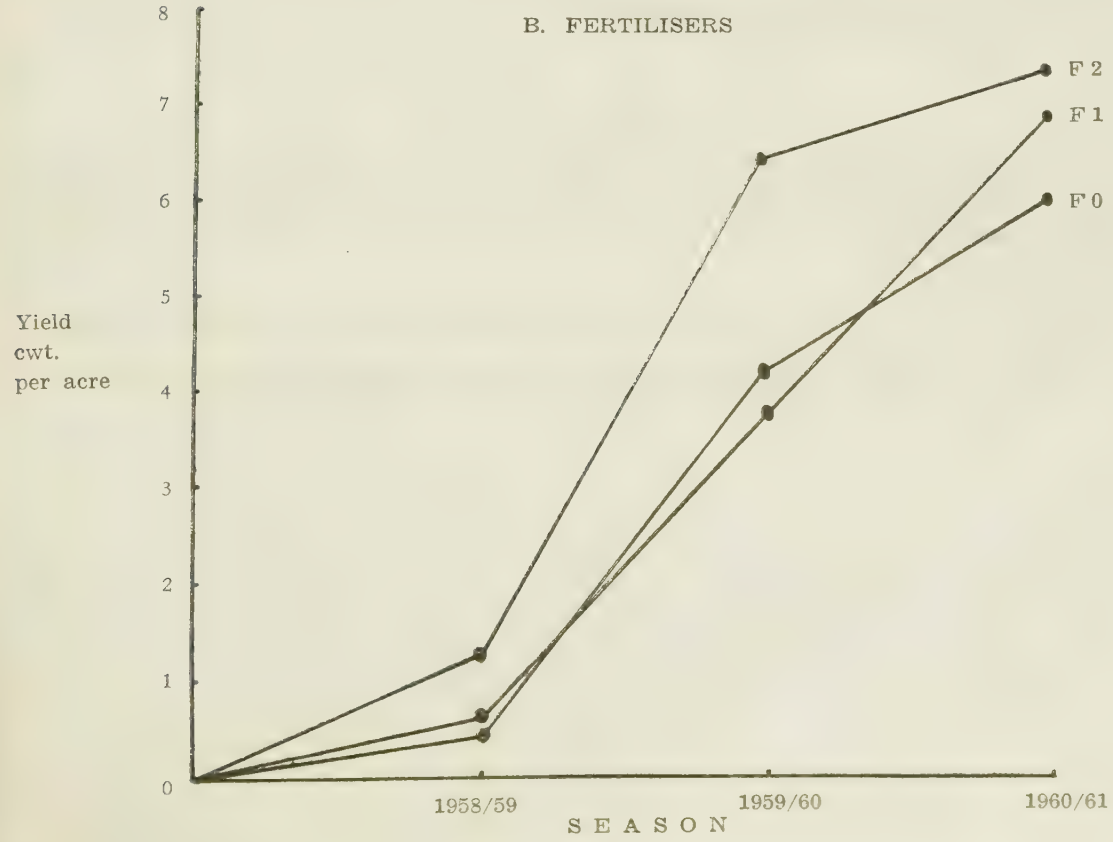
D. Mean yields for 3 years

	L_0				L_1			
	F_0	F_1	F_2	Mean	F_0	F_1	F_2	Mean
D_0	2.83	2.63	3.96	3.13	3.89	2.83	4.21	3.64
D_1	3.38	3.98	3.71	3.69	3.68	3.22	6.00	4.30
D_2	4.58	5.43	5.87	5.29	2.93	3.21	6.17	4.40
Mean	3.60	4.01	4.51	4.04	3.50	3.39	5.46	4.12

Least significant differences (P = 0.05)	1958-59	1959-60	1960-61
D and F means	0.38	1.08	N.S.
Body of the table	0.65	1.88	N.S.

FIGURE I.—Main effects of farmyard manure and fertilisers on yields of clean coffee over three seasons.





Farmyard manure applied in the planting hole gave significant increases in yield in the first two crops but not in the third crop. Over the three year period farmyard manure increased yields by 18% when applied at 20 lbs. per tree and by 43% when applied at 40 lbs. per tree.

A basal dressing of artificial fertilizers applied at planting time had no significant effect on yields. Annual top dressings of artificial fertilizers, applied in three parts, gave significant increases in yield in the first two crops but not in the third crop. Over the three year period the fertilizer top dressings increased yields by 41%.

Lime applied at planting time produced no significant effect on yield.

The yield responses to farmyard manure and artificial fertilizers are shown in Figure 1, which show the average yields for the first three cropping seasons.

DISCUSSION

The results clearly show the value of farmyard manure, applied in the planting hole, in establishing robusta coffee on the 'Rweya' soils and increasing yields in the first three years.

The basal dressing of N.P.K. fertilizer applied at planting time did not increase either the growth rate or the yield. This may be due to the root system at planting time being too small to take up the nutrients before they became fixed in the soil or leached out by rain water.

It is considered that the effect of the annual top dressings of artificial fertilizers was caused largely, if not entirely, by the nitrogen component of the N.P.K. fertilizer. A complete grass mulch cover was permanently maintained on the coffee soil from the date of planting and this would have added considerable quantities of phosphate and potash to the soil following decomposition.

ACKNOWLEDGEMENTS

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A NOTE ON THE ROOT DEVELOPMENT OF ARABICA COFFEE AT MBIMBA

By R. A. BULL, Plant Physiologist

INTRODUCTION

This note summarises and discusses the results obtained by Mr. I. J. Thompson, Officer-in-Charge, Mbimba Experiment Station, Mbozi, Southern Highlands Province, who used a root-washing technique to examine the root systems of Arabica coffee plants of various ages growing under various treatments at Mbimba. The investigation was undertaken to ascertain whether the idea that coffee roots were restricted to the planting hole at Mbimba was correct.

METHODS

Each tree examined was classified as "vigorous", "fair" or "below average", and roots were exposed by washing away surrounding soil by a water spray. No attempt was made to retain roots in their original position, but after washing had been completed measurements were made of

(a) the depth to which the tap root had penetrated
(b) the average length of lateral roots
(c) the length of the longest lateral root
(d) the number of laterals
(e) the depth at which the deepest lateral emerged from the stem.

The development of secondary and tertiary roots was estimated by Mr. Bull by scoring Mr. Thomson's photographs of root systems.

Root development was compared in trees of various ages which had been irrigated or not irrigated (both in normally spaced and hedge-planted coffee) and also in copper-sprayed and non-sprayed trees. The trees sampled were in different experiments and of various genetic origins but in every case there was only one replicate of each treatment examined and the results cannot therefore be assessed statistically.

RESULTS

These are given in Table 1 and summarised below.

1 Tap Root Development.

The depth to which the tap root had penetrated in trees of various ages is plotted in Figure I.

(a) *Tap root growth*

In vigorous non-irrigated trees tap root penetration proceeds progressively to a depth of about six feet which is reached in 3½ years. After this the curve flattens off rather abruptly but it is not possible to decide from the data whether this is an age effect or caused by the occurrence of more compacted soil at about six feet below the surface. There is no evidence that penetration of the tap root below the bottom of the planting hole (24" depth) is in any way impeded.

TABLE 1.

Root Development in Arabica Coffee at Mbimba.

Age in Field	*Location*	*Variety*	*Pruning System*	*Treatment*	*Condition of tree*	*T.R.D.*	*A.M.L.*	*L.L.L.*	*No. Lats*	*D.D.L.*	*D.F.R.*
½ year	Seed garden	P313	M.S.	—	Vigorous	1′.10″	1′.2″	1′.5″	6	4″	3
1½ years	Mbo/22	P351	M.S.	(Guard Row)	Vigorous	3′.1″	2′.6″	3′.0″	6	6″	1.5
2½ years	Mbo/16	N?	M.S.	(Guard row)	Vigorous	3′.5″	3′.2″	3′.9″	6	5″	2.5
3½ years	Mbo/10	"Lunji"	M.S.	Unirrigated	Vigorous	6′.4″	3′.9″	4-.8″	6	5″	3
3½ years	Mbo/10	"Lunji"	M.S.	Irrigated	Vigorous	4′.4″	4′.1″	4′.5″	6	7″	1.5
3½ years	Mbo/10	"Lunji"	M.S.	Irrigated	Below average	3′.1″	2′.5″	2′.10″	6	8″	3
4 years	Mbo/1	?	S.S.	Guard row	Fair	5′.6″	3′.8″	4′.4″	4	1′.1″	1
5 years	Mbo/0/11	P348	M.S.	Unirrigated	Vigorous	7′.8″	5′.6″	6′.4″	4	1′.0″	1
5 years	Mbo/0/11	N128	M.S.	Unirrigated	Below average	3′.6″	5′.5″	7′.8″	4	5″	1
5 years	Mbo/0/9	R15	M.S.	Irrigated	Vigorous	4′.3″	5′.4″	6′.4″	6	3″	3
5 years	Mbo/0/9	R15	M.S.	Unirrigated	Vigorous	7′.4″	5′.2″	6′.0″	4	4″	2.5
5 years	Mbo/0/9	R15	M.S.	Unirrigated	Below average	3′.8″	3′.11″	4′.5″	4	4″	2
5½ years	Mbo/0/12	H66	Unpruned	Unirrigated Hedge-planted	Vigorous	4′.0″	3′.6″	4′.6″	4	6″	3
5½ years	Mbo/0/12	H66	Unpruned	Irrigated Hedge-planted	Vigorous	2′.6″	2′.11″	3′.6″	5	9″	1
5½ years	Mbo/7	N128	M.S.	Copper-sprayed	Vigorous	3′.6″	4′.5″	5′.6″	7	7″	1
5½ years	Mbo/7	N128	M.S.	No Copper	Vigorous	4′.1″	4′.4″	7′.2″	6	8″	2.5
13 years	Mbo/0/5	F689	M.S.	Unirrigated	Vigorous	6′.10″	6′.9″	8′.4″	6	5″	2

Notes: T.R.D. = Depth to which tap-root was traced; A.M.L. = Average length of main lateral roots; L.L.L. = Length of longest lateral roots; No. Lats = Number of main lateral roots; D.D.L. = Depth at which deepest lateral root emerges from axis, D.F.R. = Development of feeder roots. (Score).
M.S. = Multiple Stem; S.S. = Single Stem

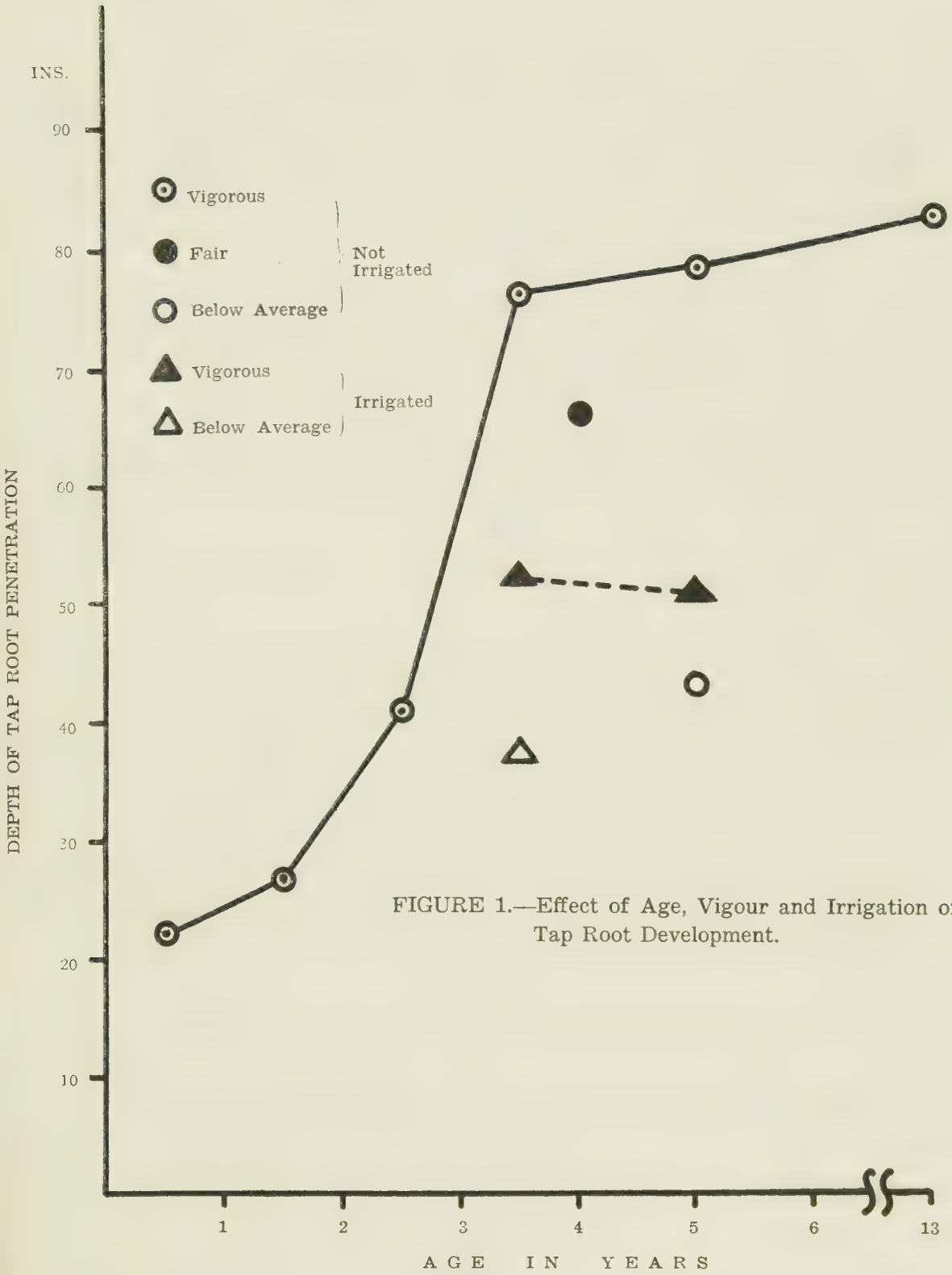

FIGURE 1.—Effect of Age, Vigour and Irrigation on Tap Root Development.

(b) *The effect of irrigation and plant vigour on tap root penetration.*

The results are summarized in Table 2 and Figure I.

Both in $3\frac{1}{2}$ and 5-year old trees irrigation reduced tap root penetration by approximately 30% in vigorous trees. In irrigated plots the $3\frac{1}{2}$-year old "below average" tree examined had a shorter tap root than an equivalent vigorous tree. A "below average" tree also had a shorter tap root in the non-irrigated plot. It can be seen from Figure I that tap root penetration in a "fair" tree is intermediate between the "vigorous" and "below average" class of tree.

(c) *The effect of hedge planting on tap root development.*

This is summarised in Table 3.

Irrigation appears to have reduced the depth of tap root penetration in both normal and hedge—planted trees, a trend similar to that seen in Table 2.

In the hedge-planting, tap root penetration was less than in normal planting regardless of whether or not irrigation was applied.

(d) *The effect of copper spraying on tap root penetration.*

There appears to be no great difference in tap root penetration in the non-irrigated sprayed and unsprayed trees examined, but in both trees tap root penetration was only about 50—60% of that in equivalent non-irrigated unsprayed trees elsewhere.

2. Lateral Root Development.

The mean length of lateral roots in trees of various ages is plotted in Figure II

(a) *Lateral root growth.*

In the vigorous non-irrigated trees lateral root growth proceeds progressively throughout the age range examined from an average length of about one foot in a $1\frac{1}{2}$-year old tree to seven feet in a 13-year old tree. The curve is almost linear and gives no evidence that extension of roots from the planting hole (12" radius from the plant) into surrounding soil is in any way impeded. The curve for the length of the longest lateral root (Figure 3) shows very similar trends.

(b) *The effect of irrigation and plant vigour on lateral root development.*

This is summarised in Tables 4 and 5, and in Figures II and III.

Unlike tap root penetration, the mean length of lateral roots (or the length of the longest lateral root) does not appear to have been influenced by irrigation in the trees examined (Plates 1 and 2). Lateral root development is less in "below average" trees both in the irrigated $3\frac{1}{2}$- year old tree and in the non-irrigated 5-year old tree, but the difference is greater in the former than in the latter.

TABLE 2.

Effect of tree vigour and irrigation on tap root penetration.

Treatment	*Vigorous*		*Below*	*Average*	*Difference (vig. v. below av.)*	
	$3\frac{1}{2}$ yrs.	5 yrs.	$3\frac{1}{2}$ yrs.	5 yrs.	$3\frac{1}{2}$ yrs.	5 yrs.
	ins.	*ins.*	*ins.*	*ins.*	*ins.*	*ins.*
Irrigated	52	51	37	—	15	—
Not irrigated	76	78	—	43	—	35
Difference (irrig. V. non-irrig.)	24	27				

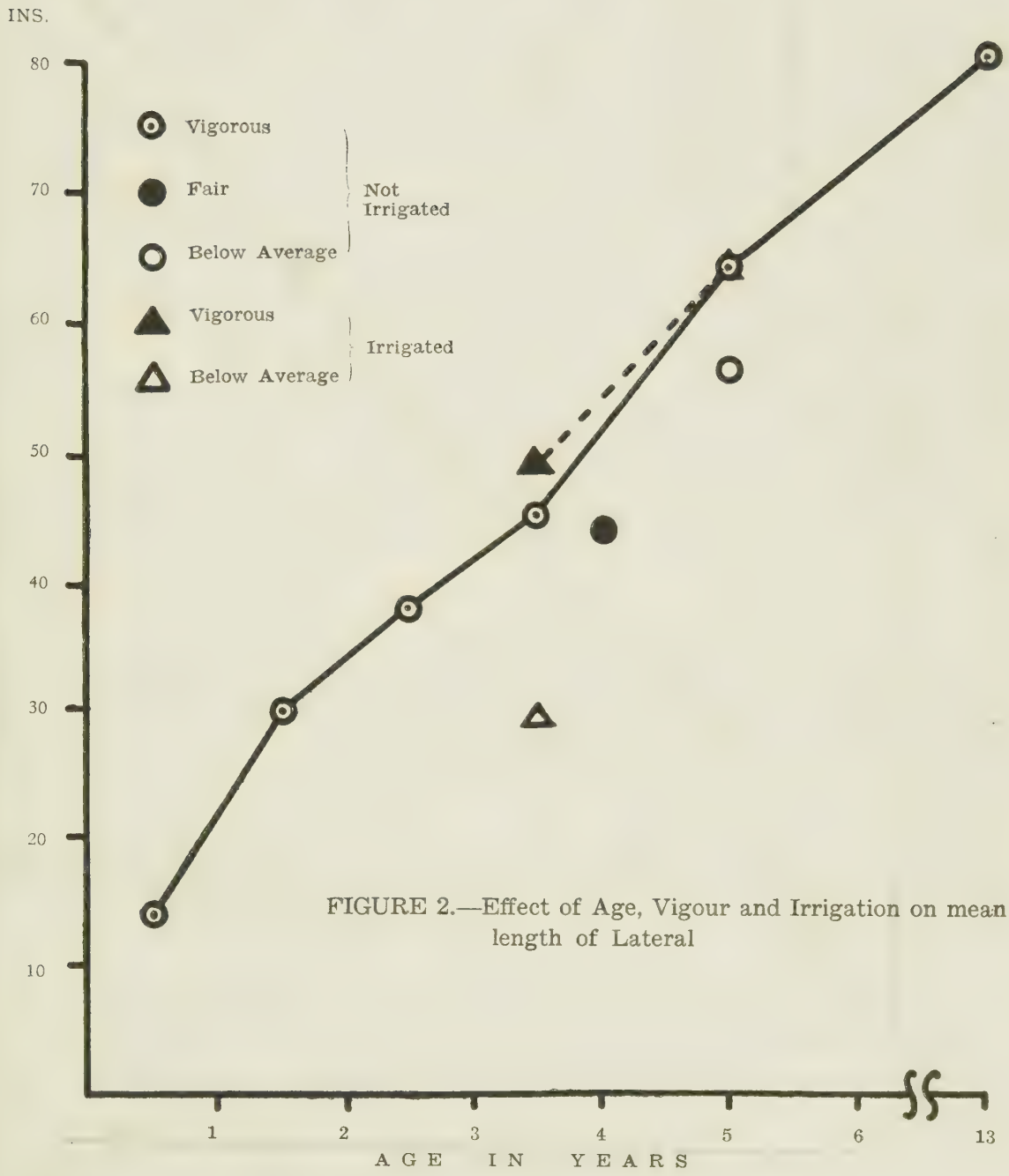

FIGURE 2.—Effect of Age, Vigour and Irrigation on mean length of Lateral

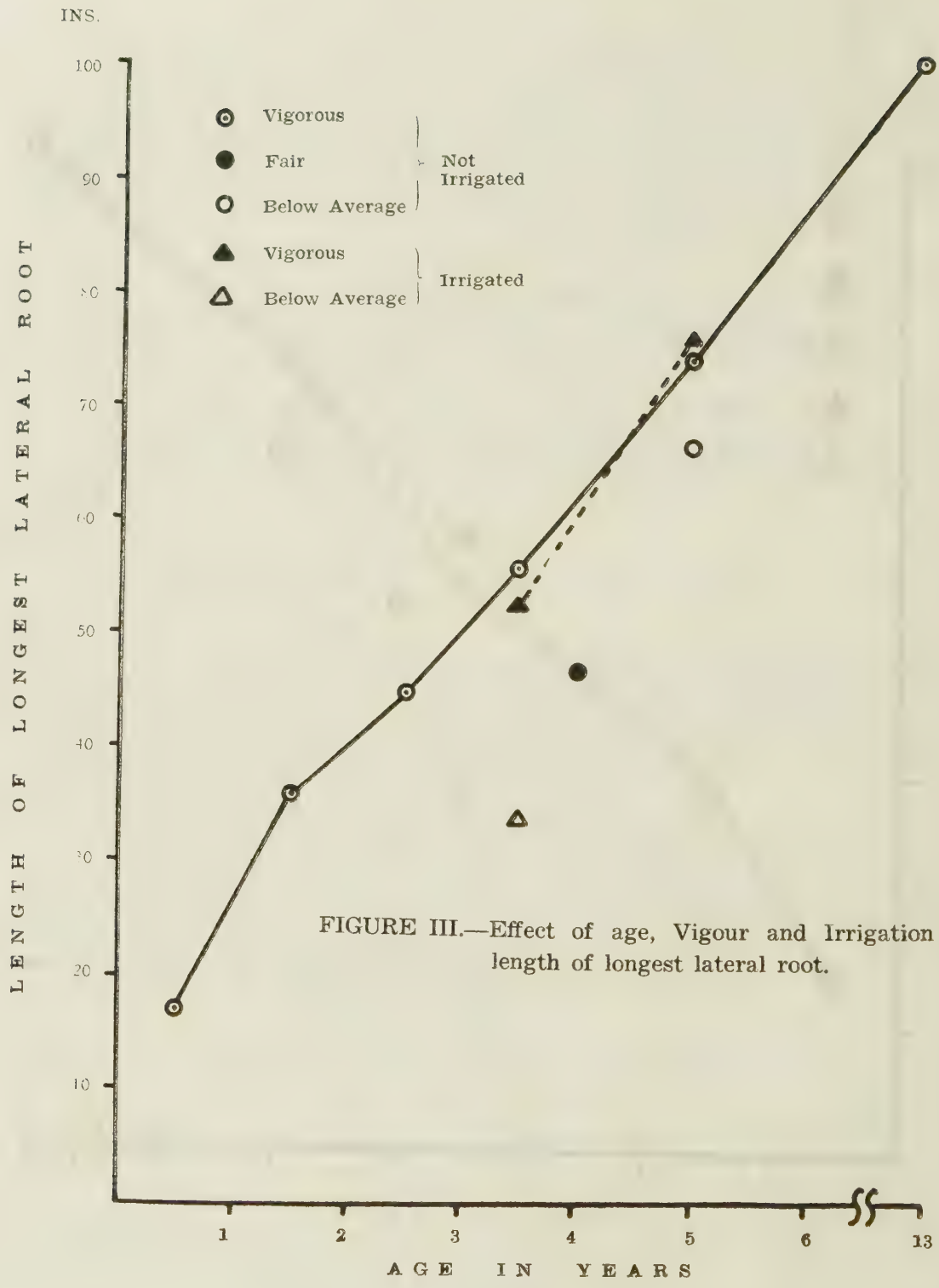

FIGURE III.—Effect of age, Vigour and Irrigation on length of longest lateral root.

TABLE 3.

Effect of planting method and irrigation on tap root penetration.

Treatment	*Normal planting*	*Hedge Planting*	*Difference (normal v. hedge)*
	ins.	*ins.*	*ins.*
Irrigated	51	30	21
Not irrigated	78	48	30
Difference (irrig. v. non-irrig.)	27	18	

TABLE 4.

The effect of irrigation and plant vigour on mean length of lateral roots.

Treatment	*Vigorous*		*Below Average*		*Difference (vig. v. below av.)*	
	3½ yrs.	5 yrs	3½ yrs.	5 yrs.	3½ yrs.	5 yrs.
	ins.	*ins.*	*ins.*	*ins.*	*ins.*	*ins.*
Irrigated	49	64	29	—	20	—
Not irrigated	45	64	—	56	—	8
Difference (irrig. v. non-irrig.)	4	0				

TABLE 5.

The effect of irrigation and plant vigour on the length of the longest lateral root.

Treatment	*Vigorous*		*Below Average*		*Difference (vig. v. below av.)*	
	3½ yrs.	5 yrs.	3½ yrs.	5 yrs.	3½ yrs.	5 yrs.
	ins.	*ins.*	*ins.*	*ins.*	*ins.*	*ins.*
Irrigated	53	76	34	—	19	—
Not irrigated	56	74	—	66.5	—	7.5
Difference (irrig. v. non-irrig.)	3	2				

TABLE 6.

The effect of irrigation and planting method on mean length of lateral roots.

Treatment	*Normal Planting*	*Hedge Planting*	*Difference (normal v. hedge)*
	ins.	*ins.*	*ins.*
Irrigated	64	35	29
Not irrigated	64	42	22
Difference (irrig. v. non-irrig.)	0	7	

(c) *The effect of planting method and irrigation on lateral root development.*

This is summarised in Table 6.

Irrigation appears to have had no effect on lateral root development in normal planting and to have decreased the mean length of lateral roots in the hedge-planted trees examined. (Plates 3 and 4). In both irrigated and non-irrigated areas the mean length of lateral roots of the hedge-planted trees is less than in normally spaced trees.

(d) *The effect of copper spraying on lateral root development.*

There is little difference between sprayed and unsprayed trees, but in both the mean length of laterals is less than in the equivalent vigorous non-irrigated trees examined.

3 THE NUMBER OF LATERAL ROOTS.

This does not differ substantially in any treatment or age class. It is interesting that hedge-planting does not appear to have influenced the number of lateral roots produced.

4 THE DEPTH OF THE DEEPEST LATERAL ROOT.

The figures for this parameter are irregular. Although vigorous irrigated 5-year old trees appear to have shallower lateral roots than non-irrigated trees of a similar age the figures for the latter are variable and the irrigation "effect" of doubtful significance. The "below average" 5-year old non-irrigated trees had shallower lateral roots than the equivalent vigorous trees but this trend was not observed in $3\frac{1}{2}$-year old irrigated trees. In the hedge-planting the irrigated tree had a deeper lateral root system. Copper spraying has had little effect.

5 THE DEVELOPMENT OF SECONDARY AND TERTIARY ROOTS.

Secondary and tertiary roots are approximately equivalent to what Nutman (1933) has termed "feeder-bearers and feeders" respectively. The development of these was assessed by visual scoring of photographs of exposed root systems on the basis of a 1, 2, 3 scale for poor, fair and good development respectively.

There does not appear to be any particular pattern in feeder-root development. In $3\frac{1}{2}$-year old coffee there are fewer feeders in the irrigated tree and a similar but more pronounced trend is present in $5\frac{1}{2}$-year old hedge-planted coffee. The "below average" trees examined do not appear to have fewer feeding roots than equivalent "vigorous" trees.

DISCUSSION

As stated above since only one replicate of each treatment was examined the results cannot be analysed statistically and the intrepretation of trends demands caution. With this reservation in mind, the results suggest that it is most unlikely that at Mbimba development of a normal root system following planting is in any impeded by peculiar soil conditions. There is no suggestion than either tap or lateral roots fail to grow out of the planting hole in the usual way, and planting holes larger than the size of 2' square x 2' deep usually employed seem unlikely to confer any particular advantage as far as root development is concerned.

In normally spaced trees irrigation appears to have decreased the depth of penetration of tap roots, but has not influenced the development of lateral roots. In hedge-planted trees development of both tap and lateral root systems appears to be curtailed and this trend is even more pronounced where hedge-planted coffee is irrigated.

PLATE I.—The root system of a vigorous irrigated tree (5 years old, Selection R.15)

PLATE II.—The root system of a vigorous non-irrigated tree (5 years old, Selection R.15)

PLATE III.—The root system of a non-irrigated hedge-planted tree (5½ years old, Selection H.66)

PLATE IV.—The root system of an irrigated hedge-planted tree (5½ years old, Selection H.66)

Broadly speaking, vigorous trees appear to have a more extensively developed system of tap and lateral roots than "below average" trees and this trend appears to be independent of whether or not irrigation has been applied.

Copper spraying does not appear to influence root development in any consistent manner.

These trends are of interest but require confirmation from more extensive work in which the number of replicates examined is adequate to permit statistical examination of the results obtained.

SUMMARY

A preliminary study of coffee roots excavated by washing at Mbimba Experiment Station has shown that root development in the field subsequent to transplanting is not impeded by abnormal soil conditions. A non-statistical comparison of trees in different treatments suggests (a) that irrigation decreases the depth of peneration of tap roots but does not influence the development of lateral roots (b) hedge-planting induces a smaller root system (c) the vigour of the tree is related to the size of the root system.

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